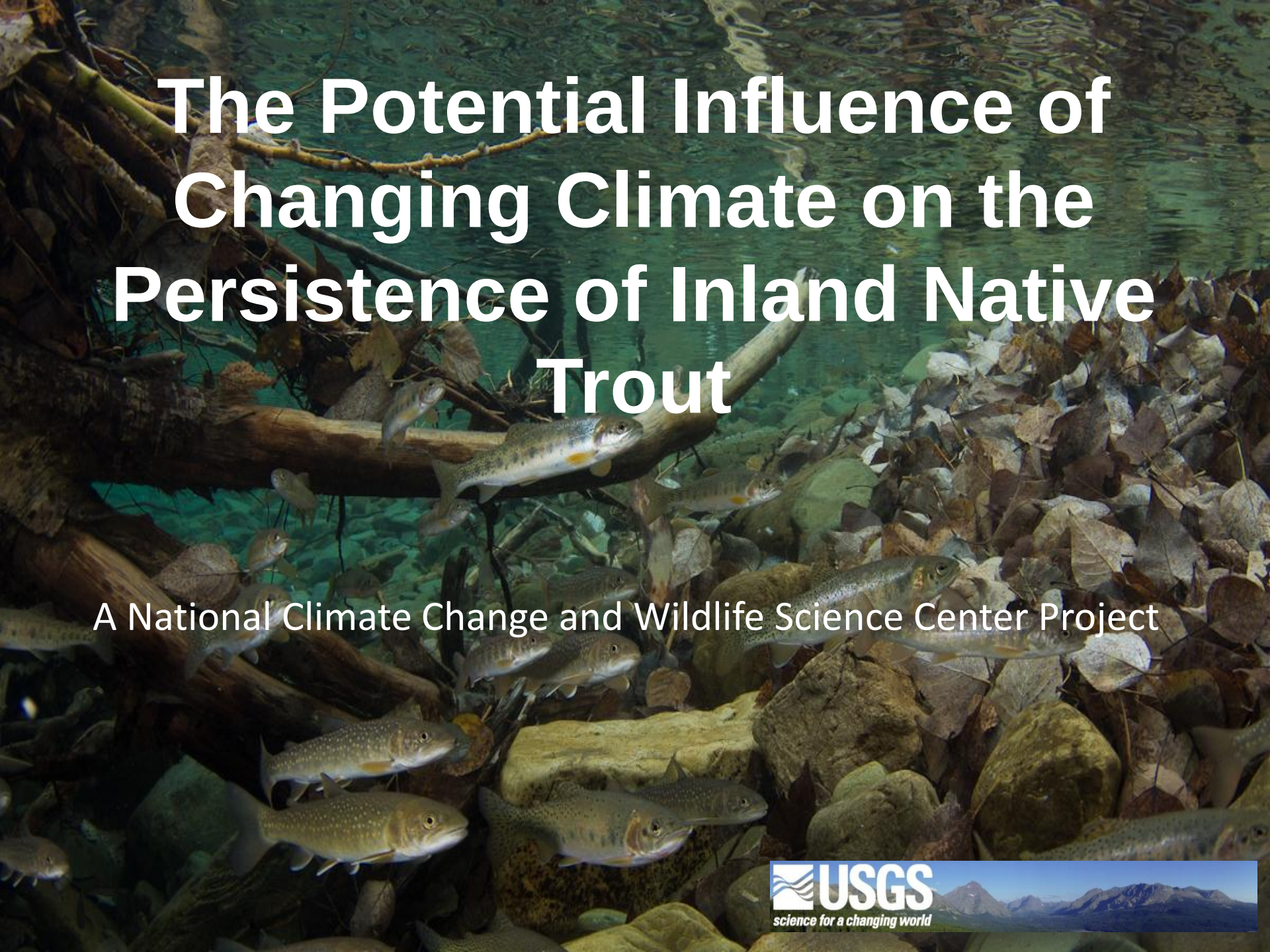

The Potential Influence of Changing Climate on the Persistence of Inland Native Trout

A National Climate Change and Wildlife Science Center Project

USGS
science for a changing world

A Collaborative Research Partnership

USGS

Jeffrey L. Kershner, Robert Al-Chokhachy, Clint Muhlfeld, Robert Gresswell – NOROCK
Steven Hostetler/Jay Alder – National Research Program - Water
Andrew Todd – Crustal Geophysics and Geochemistry

USFS

Daniel Isaak, Charlie Luce – Rocky Mountain Research Station, Boise
Seth Wenger - Rocky Mountain Research Station/Trout Unlimited

Trout Unlimited

Jack Williams, Amy Haak, Helen Neville

Colorado State University

Kurt Fausch, James Roberts

US Fish and Wildlife Service

Doug Peterson

Thanks to Jonny Armstrong for the Underwater photos

USGS
science for a changing world

Why Inland Native Trout?

- People care about trout
- Species are found throughout the mountainous habitats of the interior western US
- Generally, thermally intolerant to rapid changes in stream temperature
- Salmonids generally viewed as early indicators of climate change
- Existing threats may be accelerated by the addition of climate stressors

USGS
science for a changing world

Conserving Native Salmonids: What are the Concerns?

- Life History expression
  - Fluvial, adfluvial, resident
- Isolation, connectivity
- Habitat loss
- Non-native species

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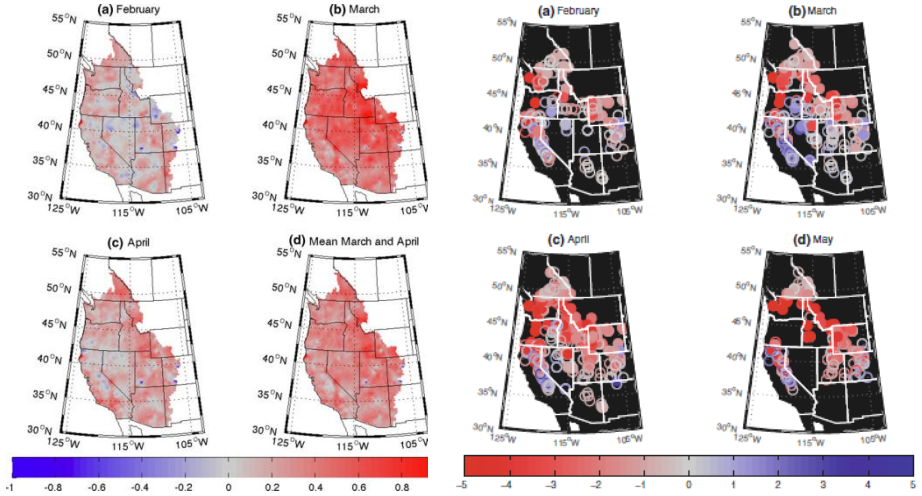
science for a changing world

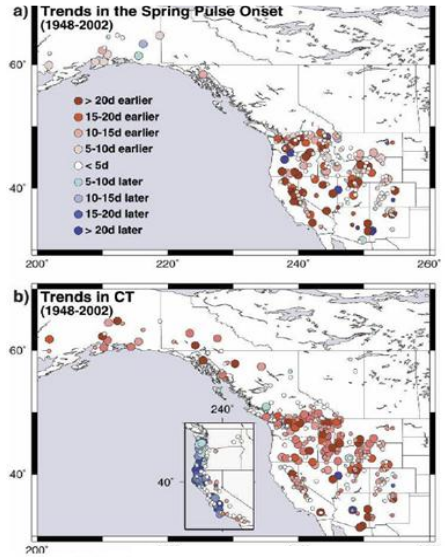
The seasonal climate-related drivers

Trends to warmer winter/spring reduced snowpack and earlier snow melt



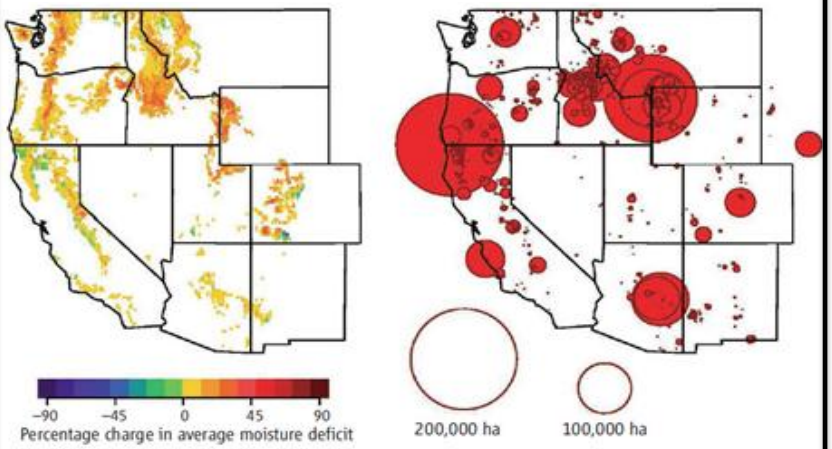
Kapnick and Hall, 2012

Altered runoff regimes



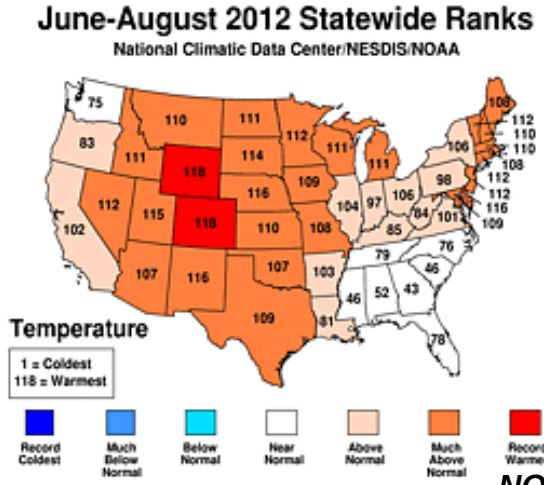
Stewart et al., 2005

Reduced surface moisture– larger wildfires



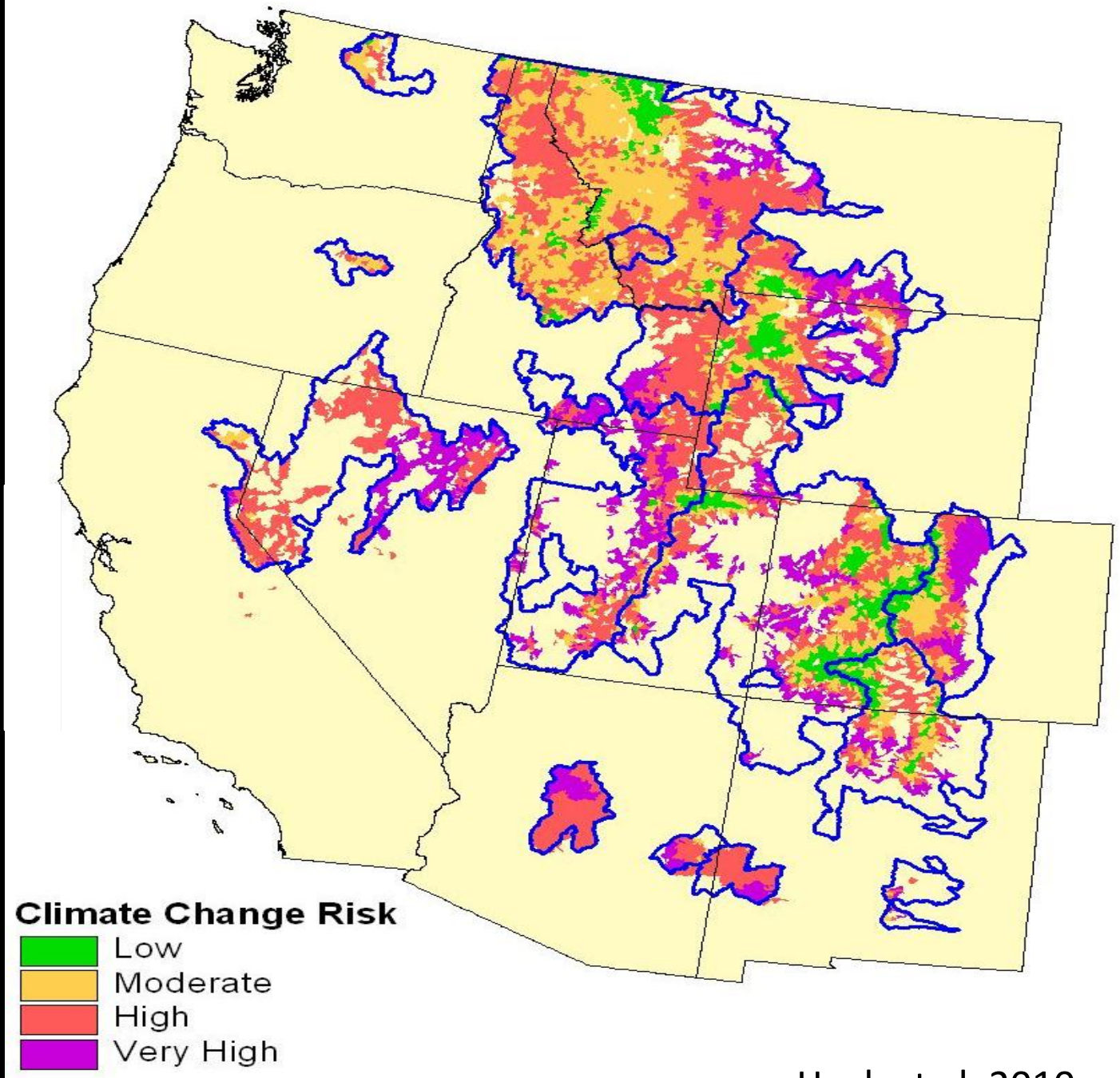
Running, 2006

Warmer summer temperatures



NOAA, 2012

Composite Climate Change Risk



Haak et al. 2010

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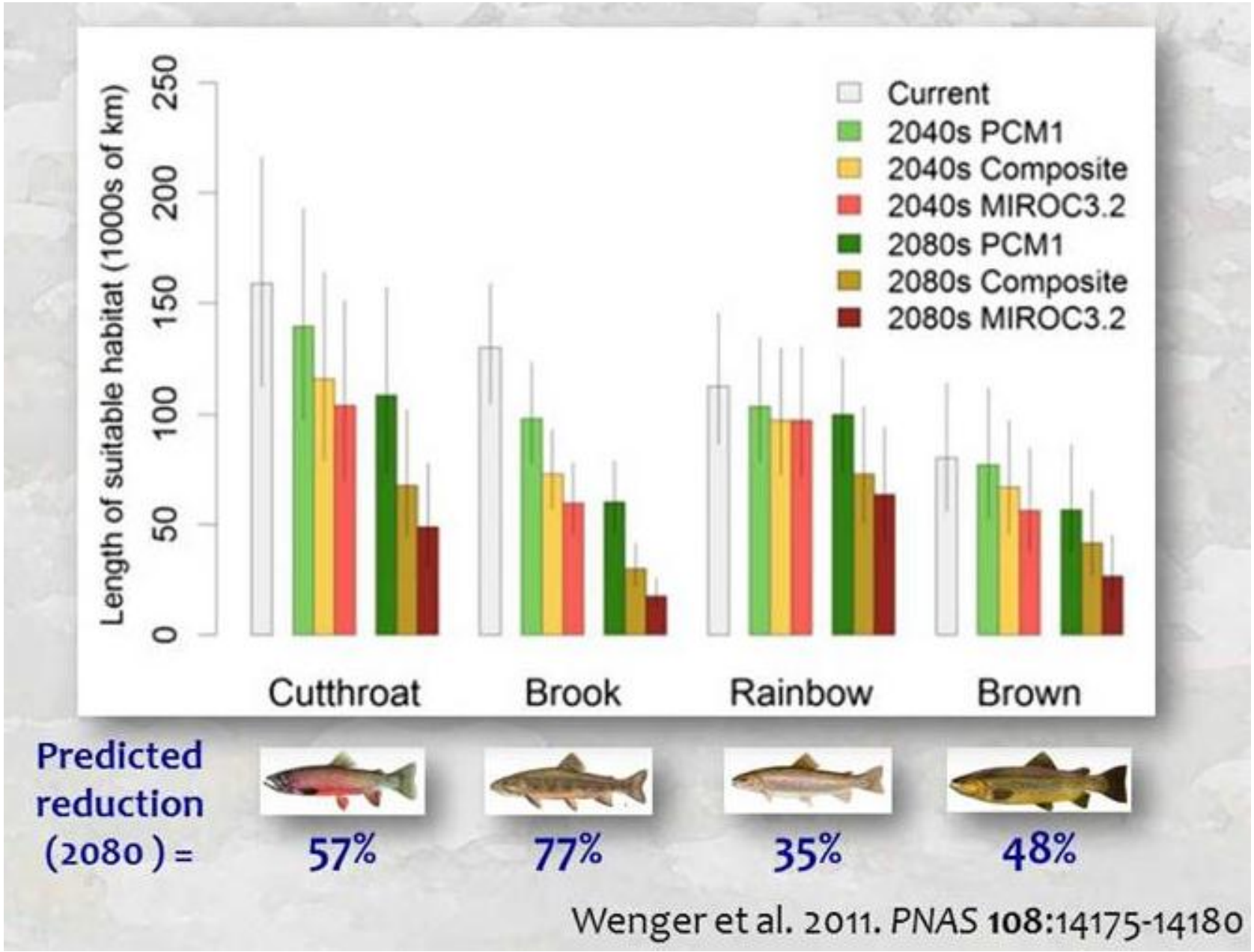
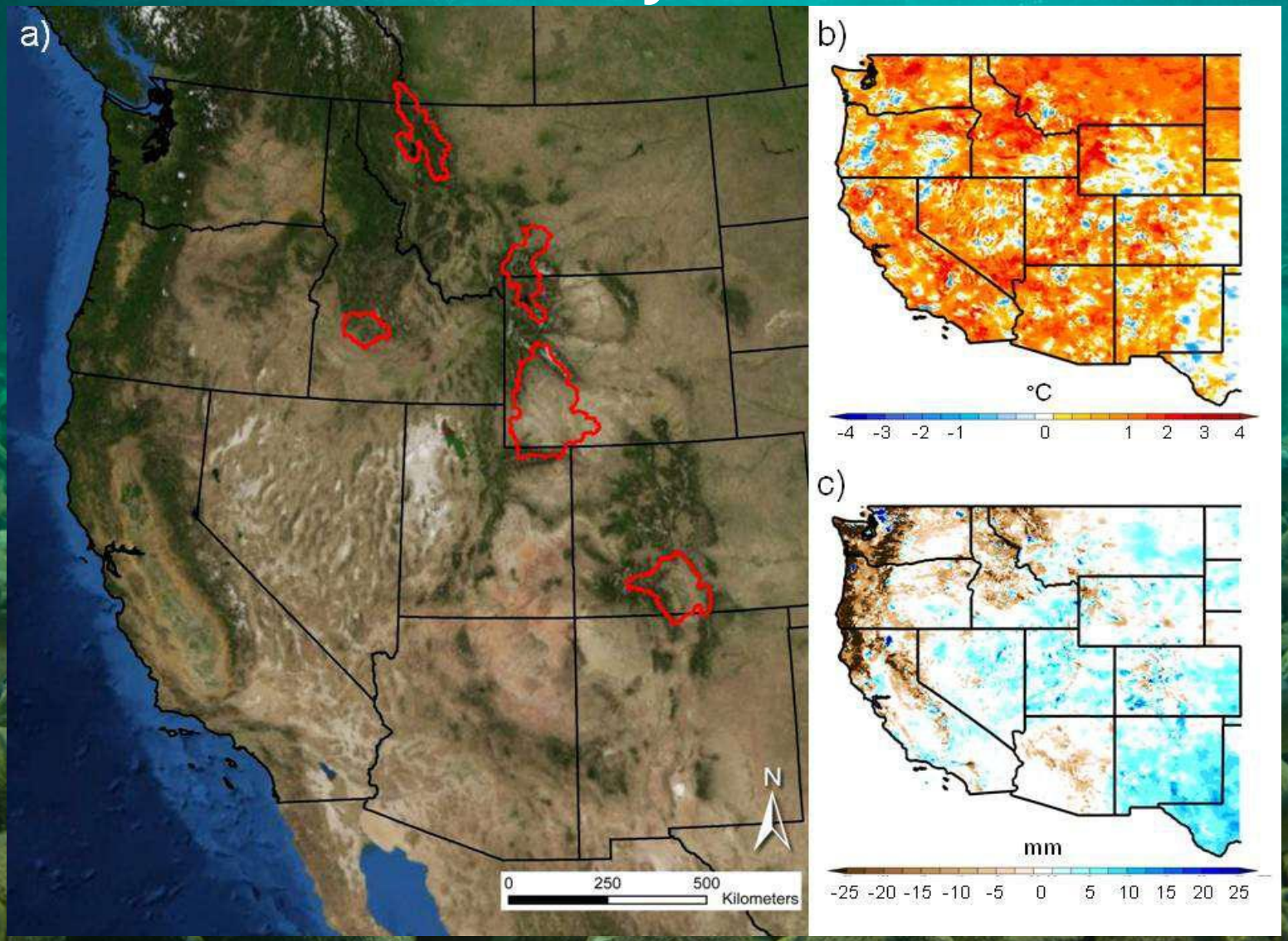
Western trout assessment



Wenger et al. 2011. *PNAS* **108**:14175-14180

Geographic Location of the Fine Scale Analyses



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Research Tasks

Task 1. Produce and compile high-resolution climate data sets.

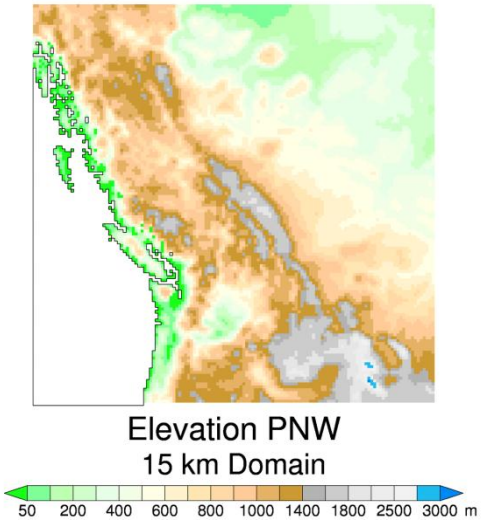
Task 2. Develop hydrologic, thermal, and geomorphic models to downscale climate effects to stream habitats.

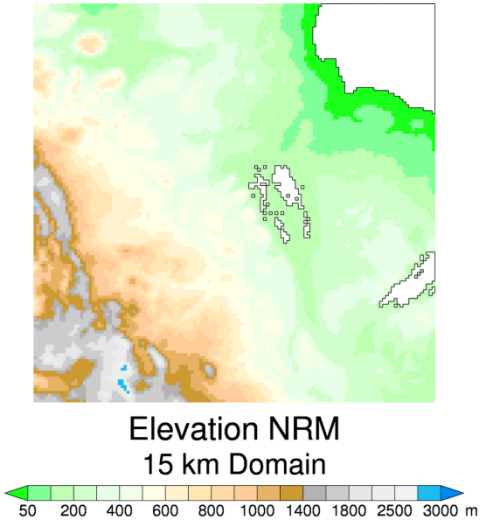
Task 3. Develop biological models that predict trout population attributes from stream habitat.

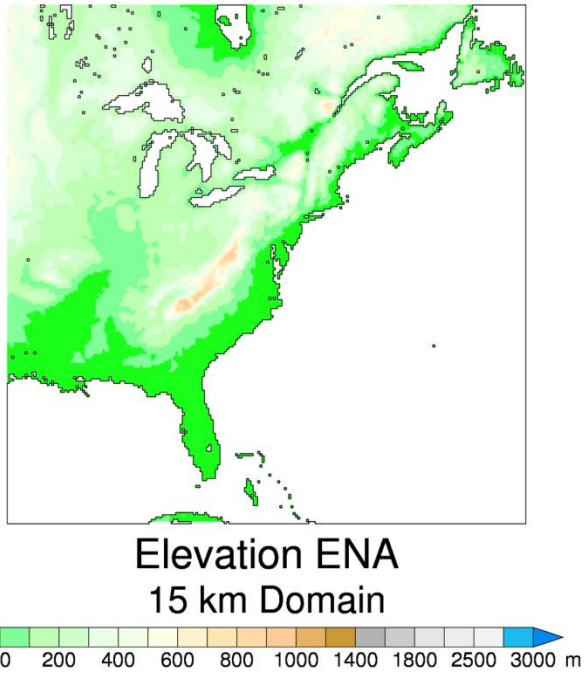
Task 4. Assess the potential effects of climate change on stream habitats and trout species

Task 5. Develop decision support tool to integrate future changes, provide risk assessments, and prioritize management options.

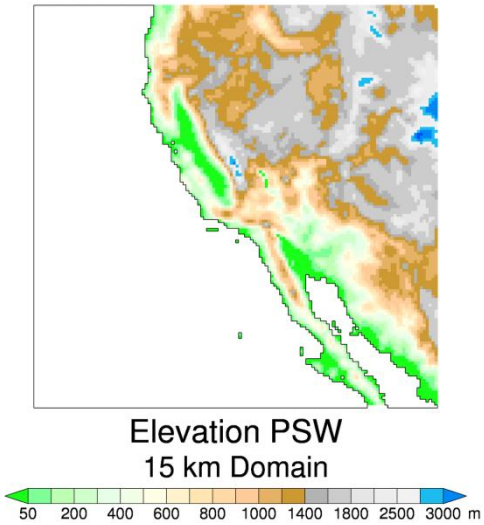
15-km domains

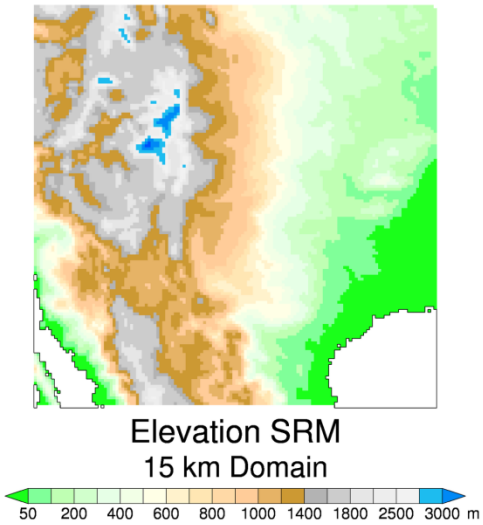






23 atmospheric levels
251X256 grid cells





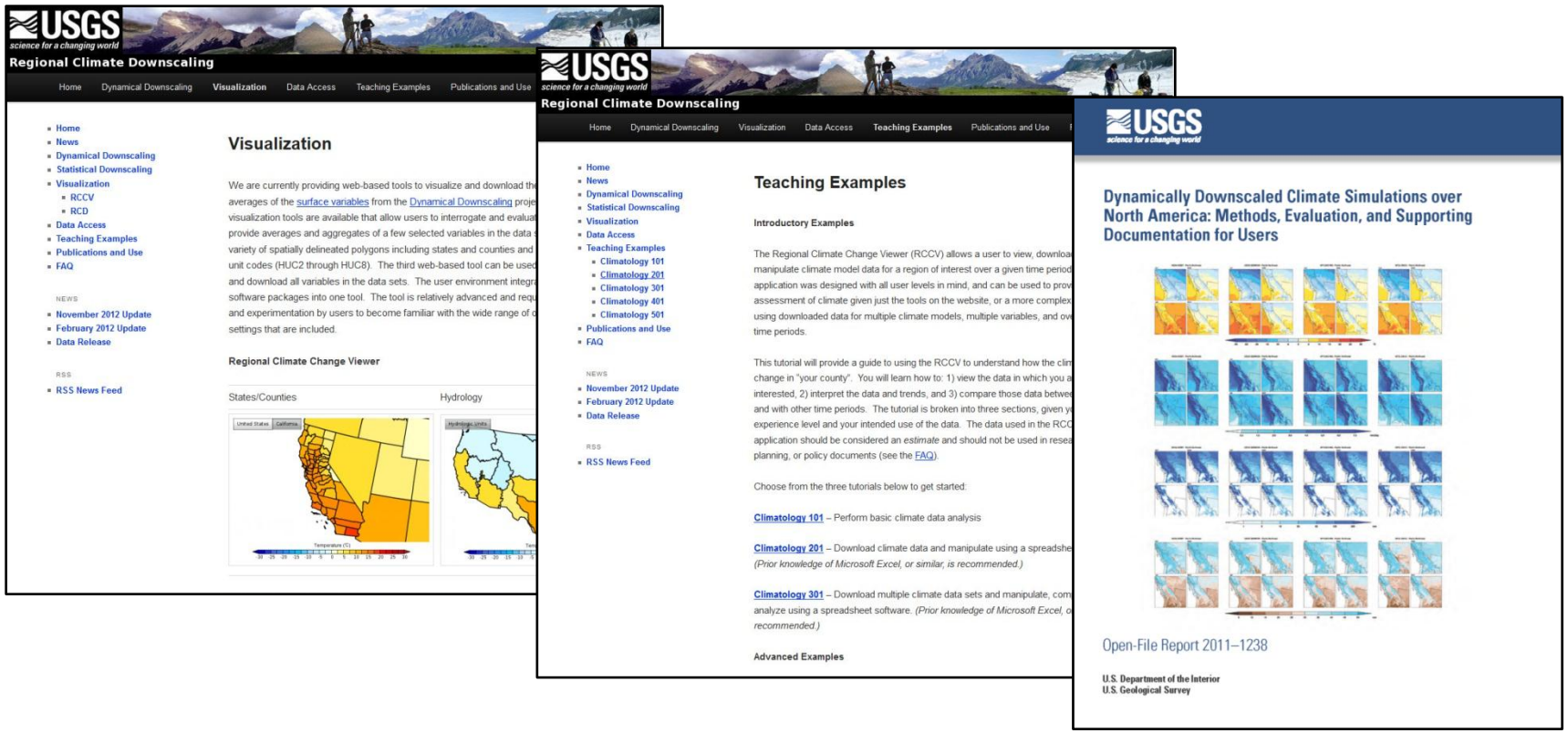
18 atmospheric levels
160X161 grid cells

Simulation periods

Driving AOGCM	North America 50 km	West 15 km	East 15 km
NCEP Reanalysis	1968-2010	1968-2010	1982-2007
MPI ECHAM5 (20C, A2)	1968-1999 2010-2099	1968-1999 2010-2099	1968-1999 2020-2099
GFDL CM2.0 (20C, A2)	1968-1999 2038-2069	1968-1999 2038-2069	1968-1999 2038-2070
GENMOM (A2)	1968-1999 2010-2099	1968-1999 2010-2099	1980-1999 2020-2080

- Output stored at 3- and 6-hr time steps
- Daily and monthly averages
- > 60 simulated and derived fields

http://regclim.coas.oregonstate.edu



Collaborations

- 3 NCCWSC projects (federal, state, universities)
- Center for Integrated Data Analytics (CIDA)
- BLM Rapid Ecosystem Assessments
- USFWS, USDAFS, NOAA, GNLCC, CSCs, WSC

New web-app release 11/8/2012

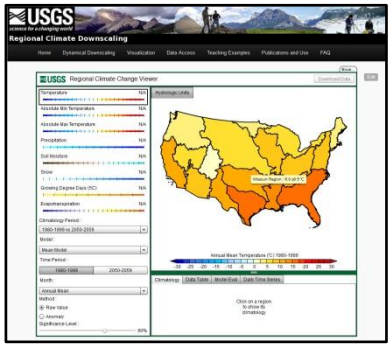
- Daily data
- Diagnostic plots
- New data sets
- 436,367 files

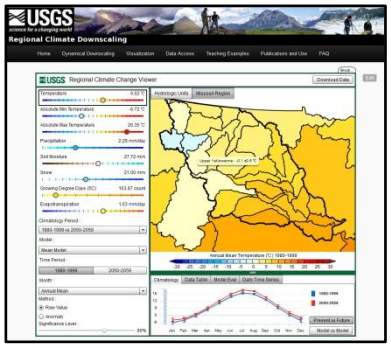
Nested regions and diagnostics

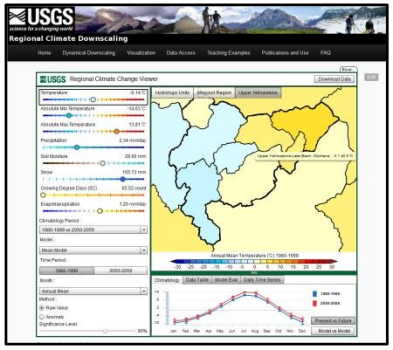
HUC2

HUC4

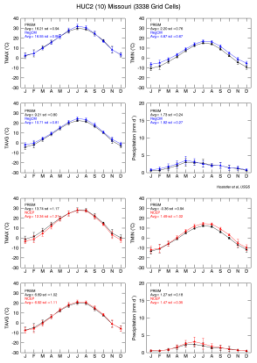
HUC8

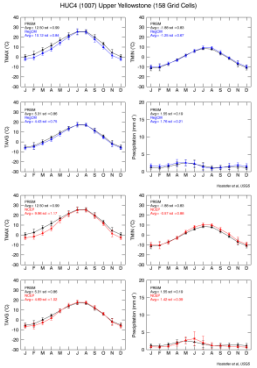


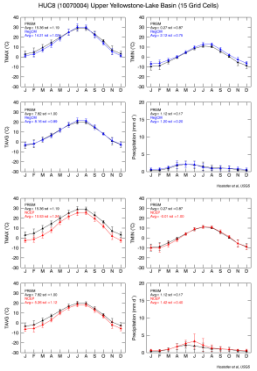




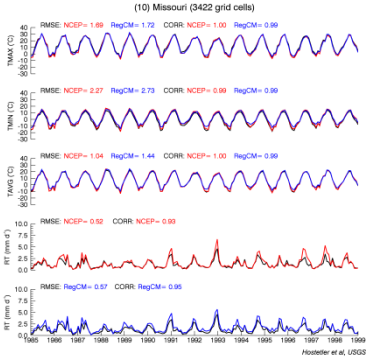
Climatology

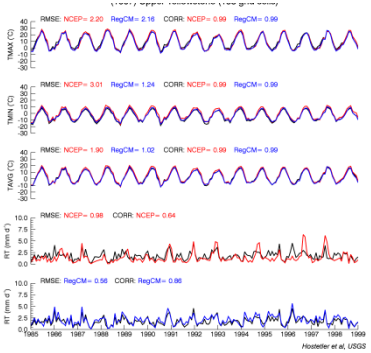


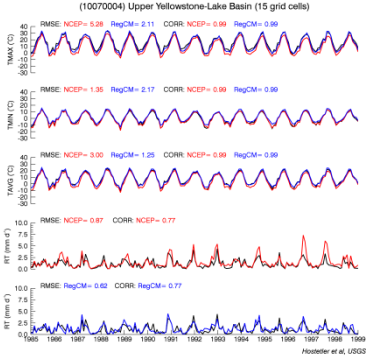




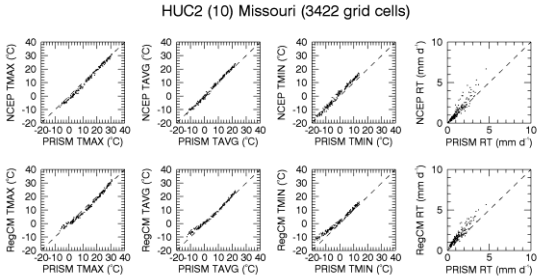
Time series

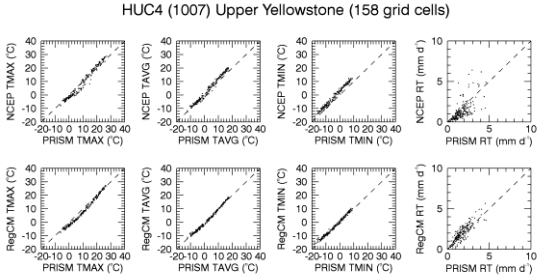


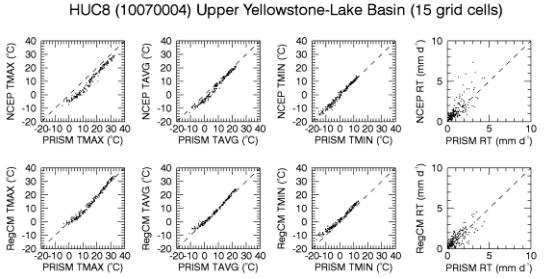




Scatter

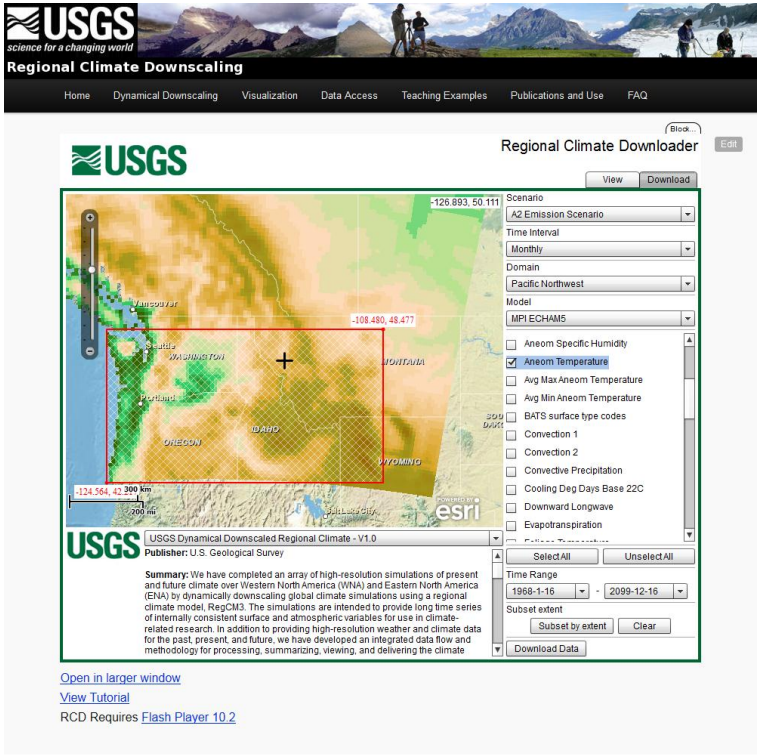


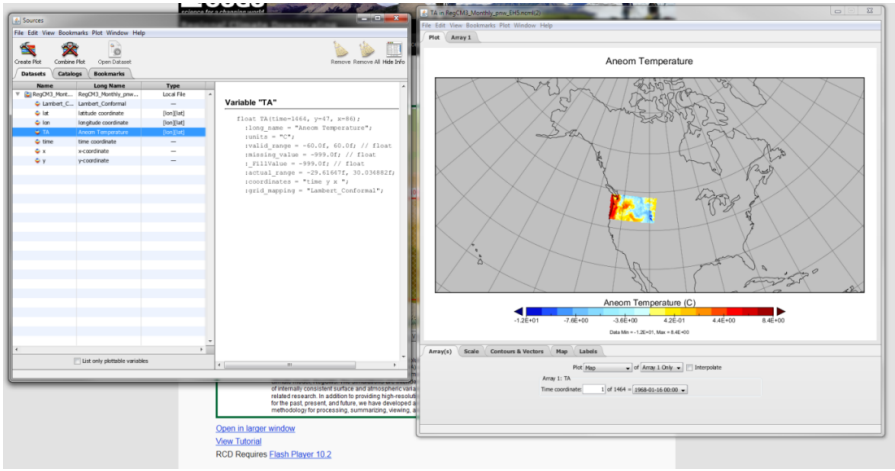




Hostetler et al.

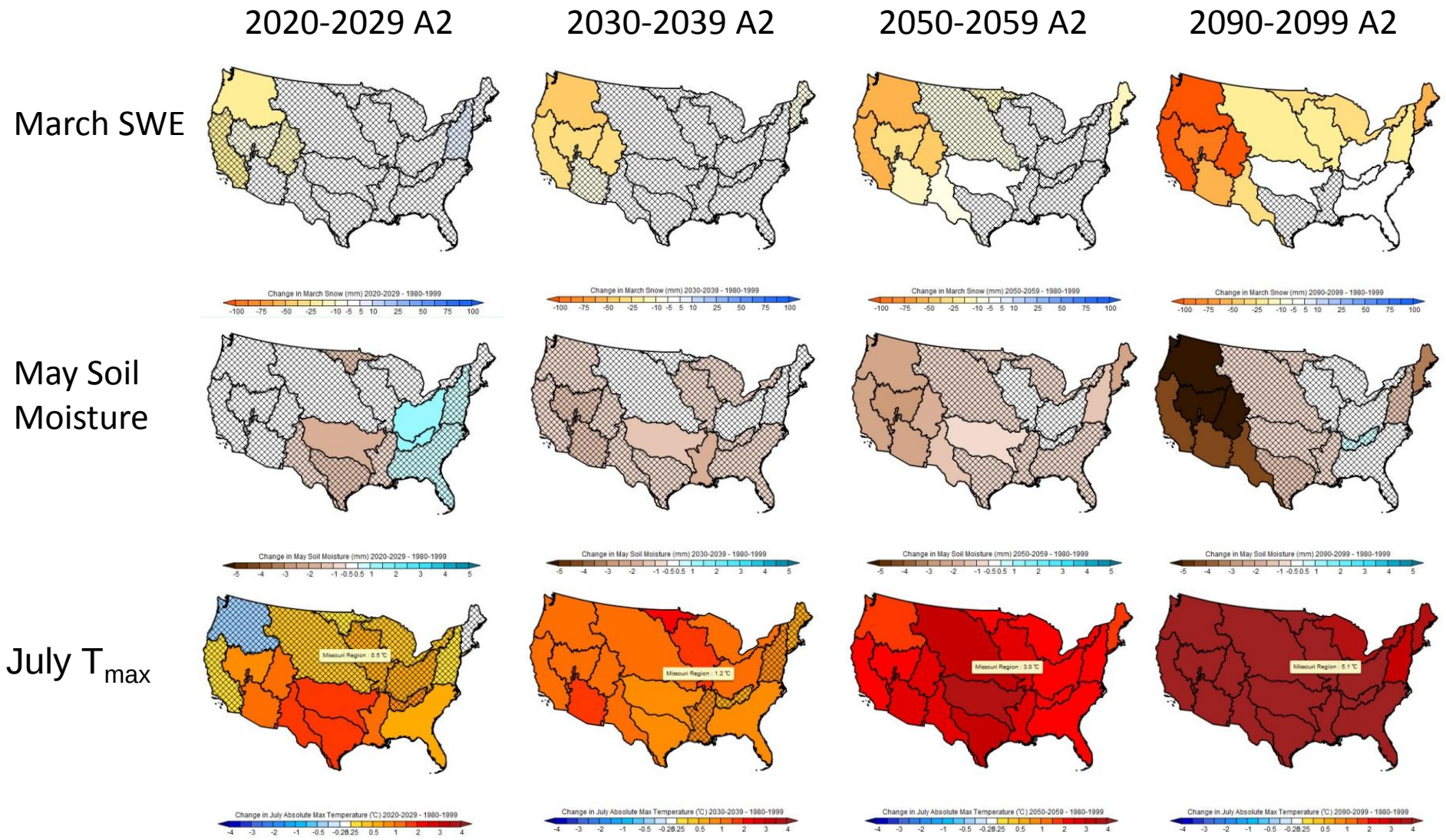
Select and download netCDF via RCD





- ftp
- USGS CIDA Geo Data Portal (shape files)

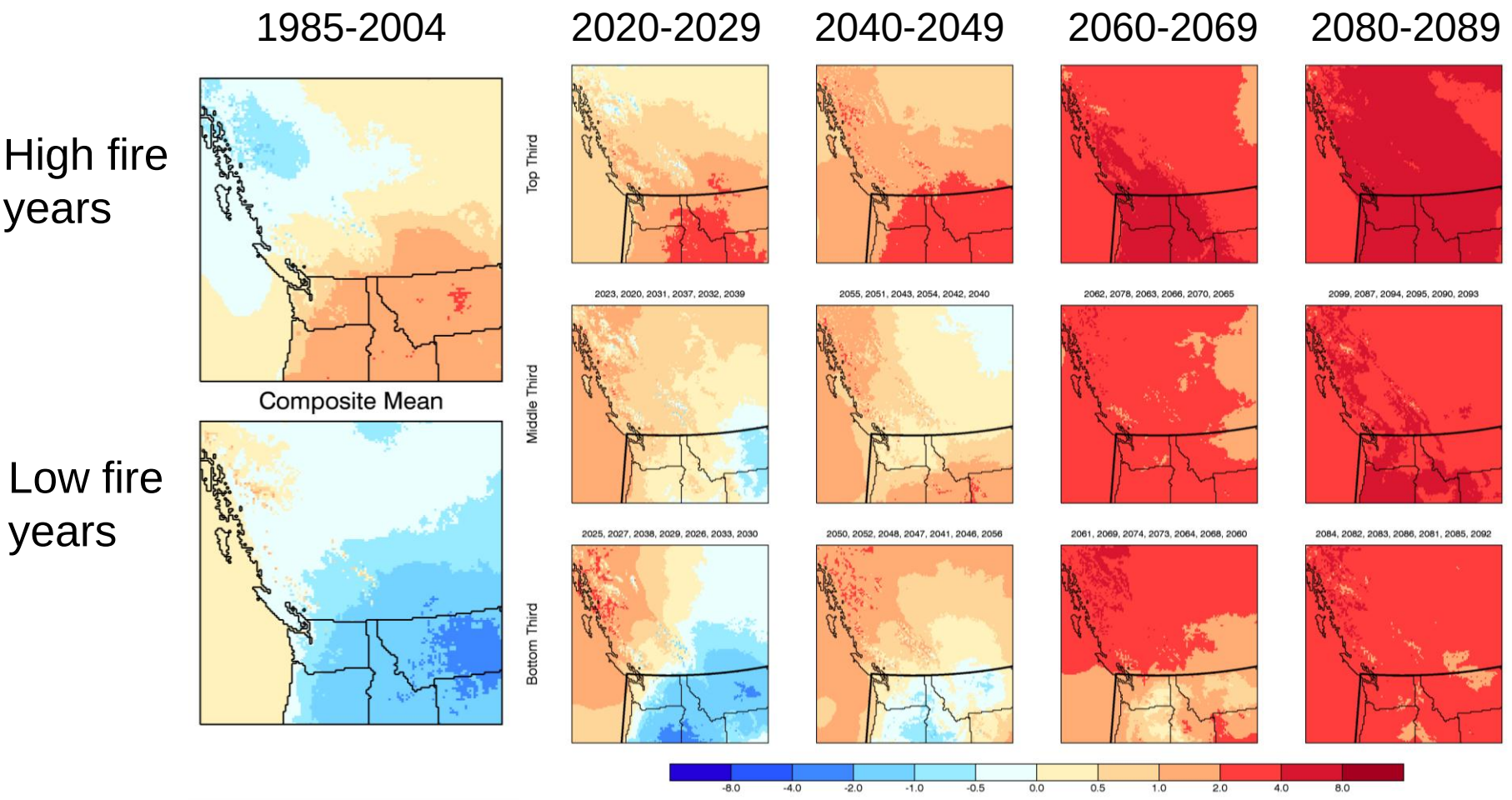
Seasonal controls of salmonid life cycles



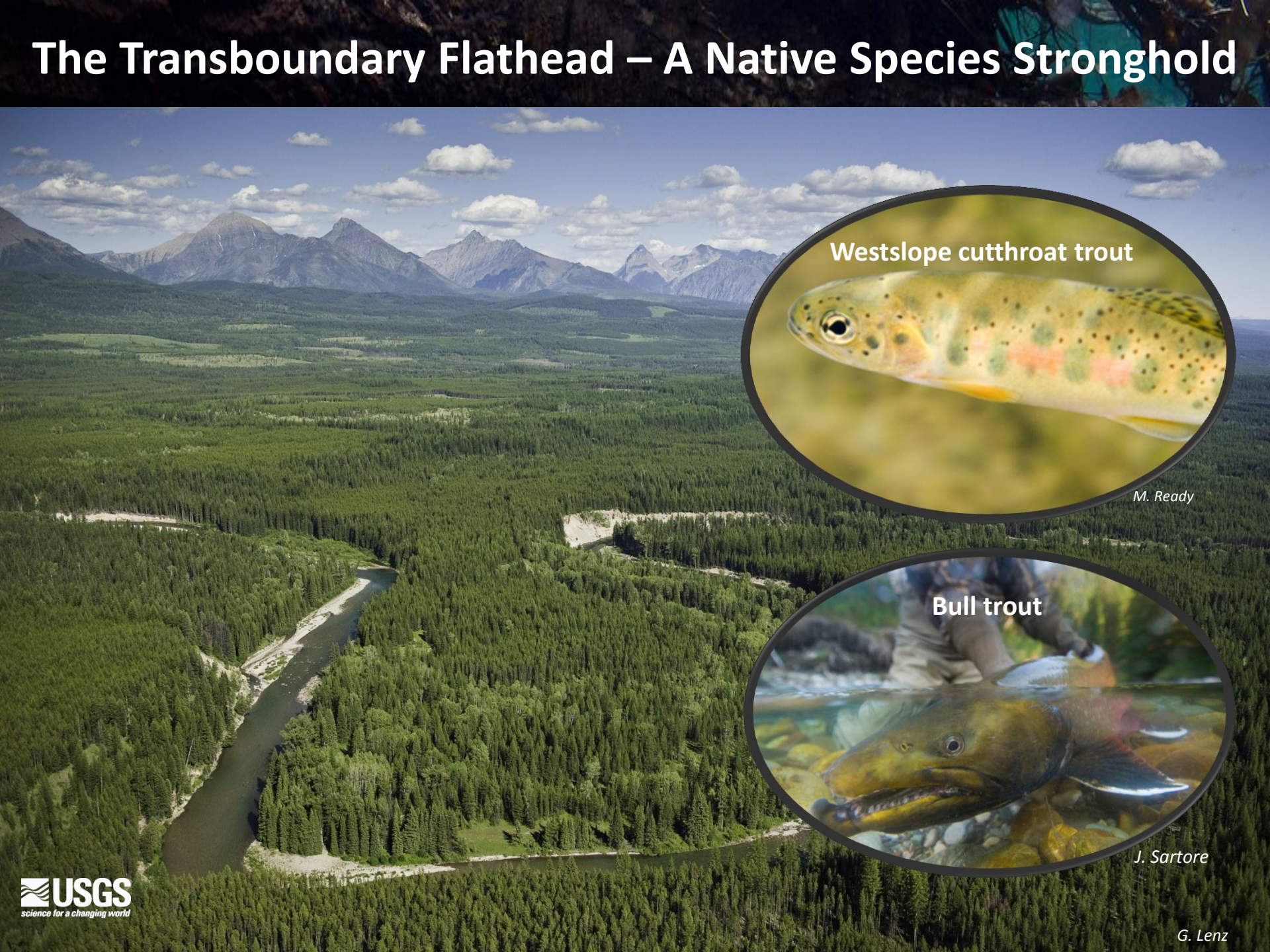
Hostetler et al.

Wildfire climatology in the Pacific NW

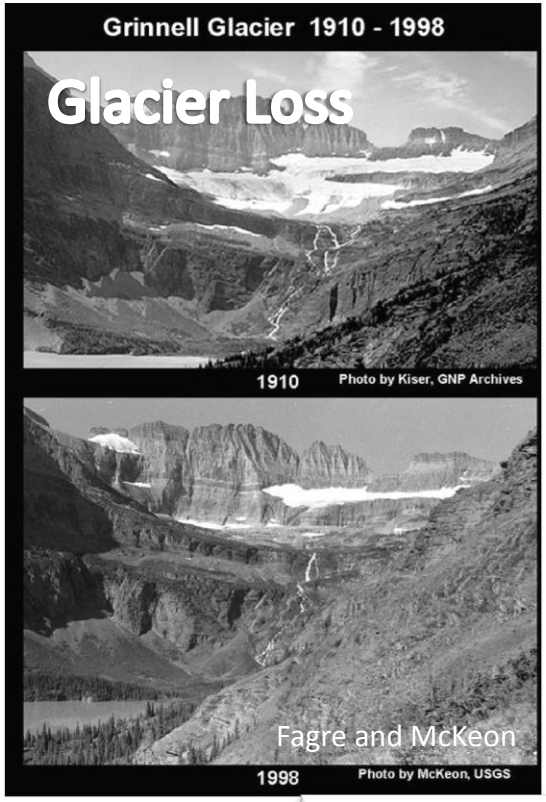
July air temperature composite anomalies



The Transboundary Flathead – A Native Species Stronghold



A landscape undergoing change



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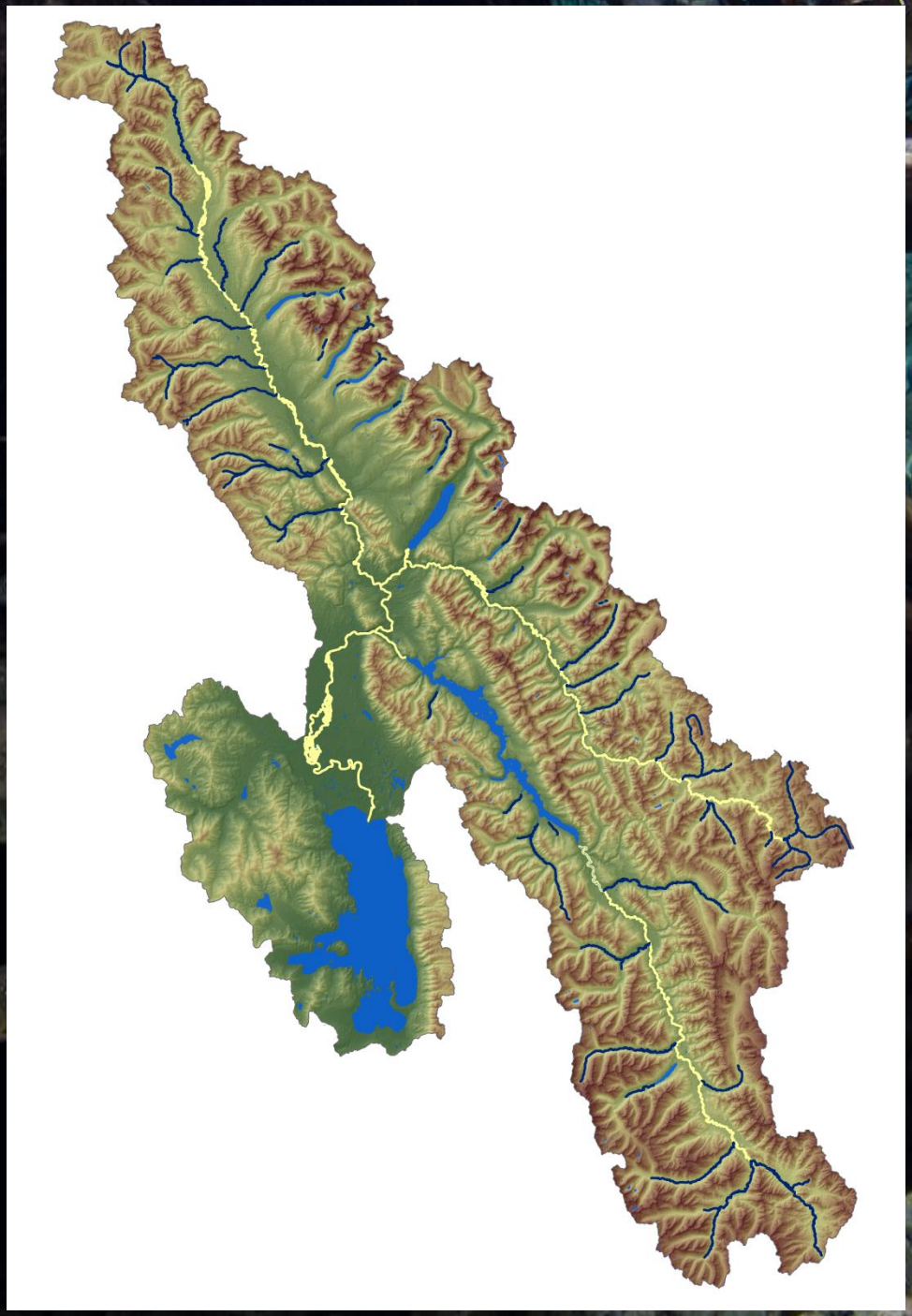
Bull Trout Critical Habitat

J. Sartore

- Spawning and Rearing
- Foraging, Migrating and Overwintering



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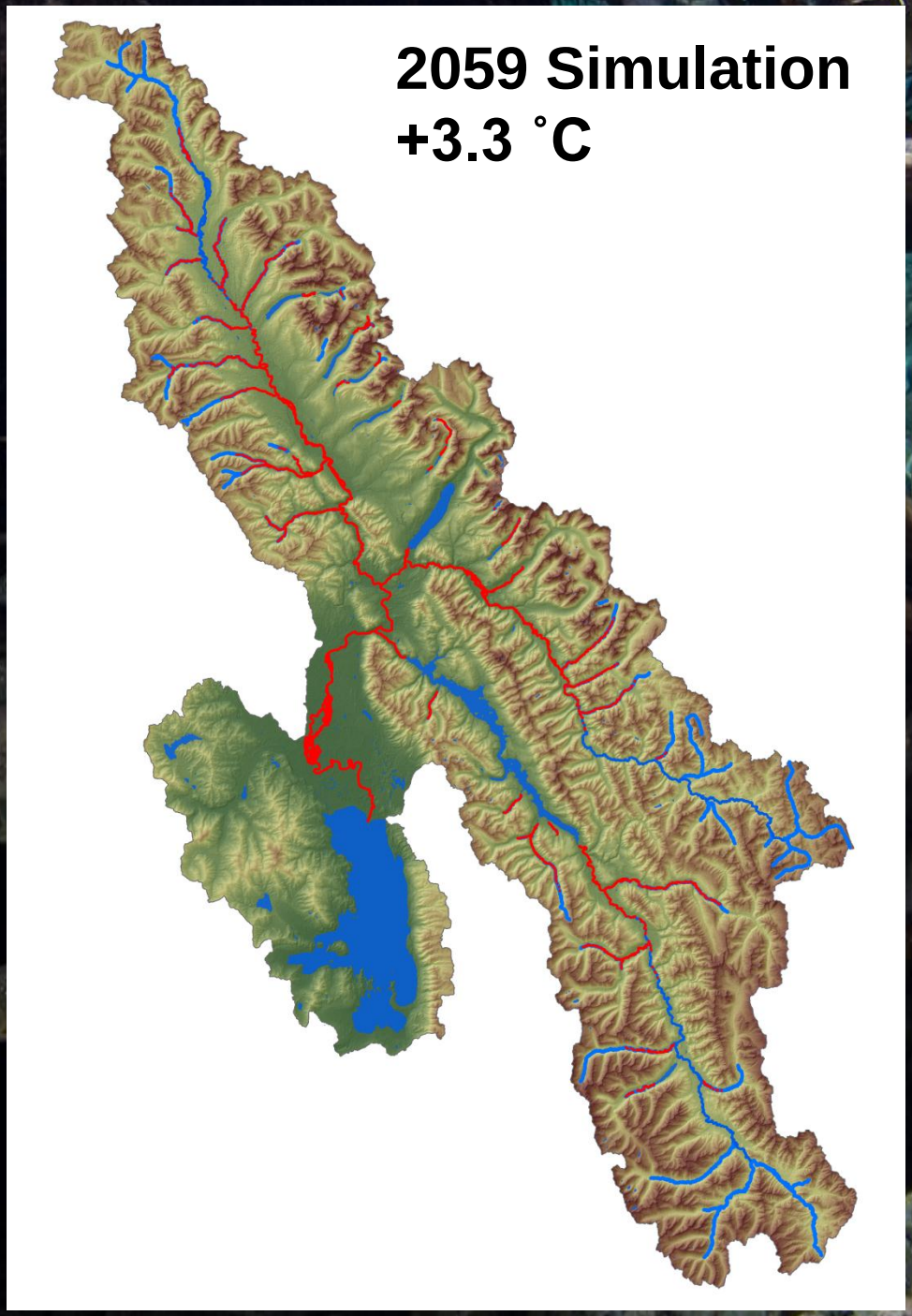
J. Sartore

- **58% Loss of FMO**
- **36% Loss of SR**

Exceedence of Thermal Thresholds

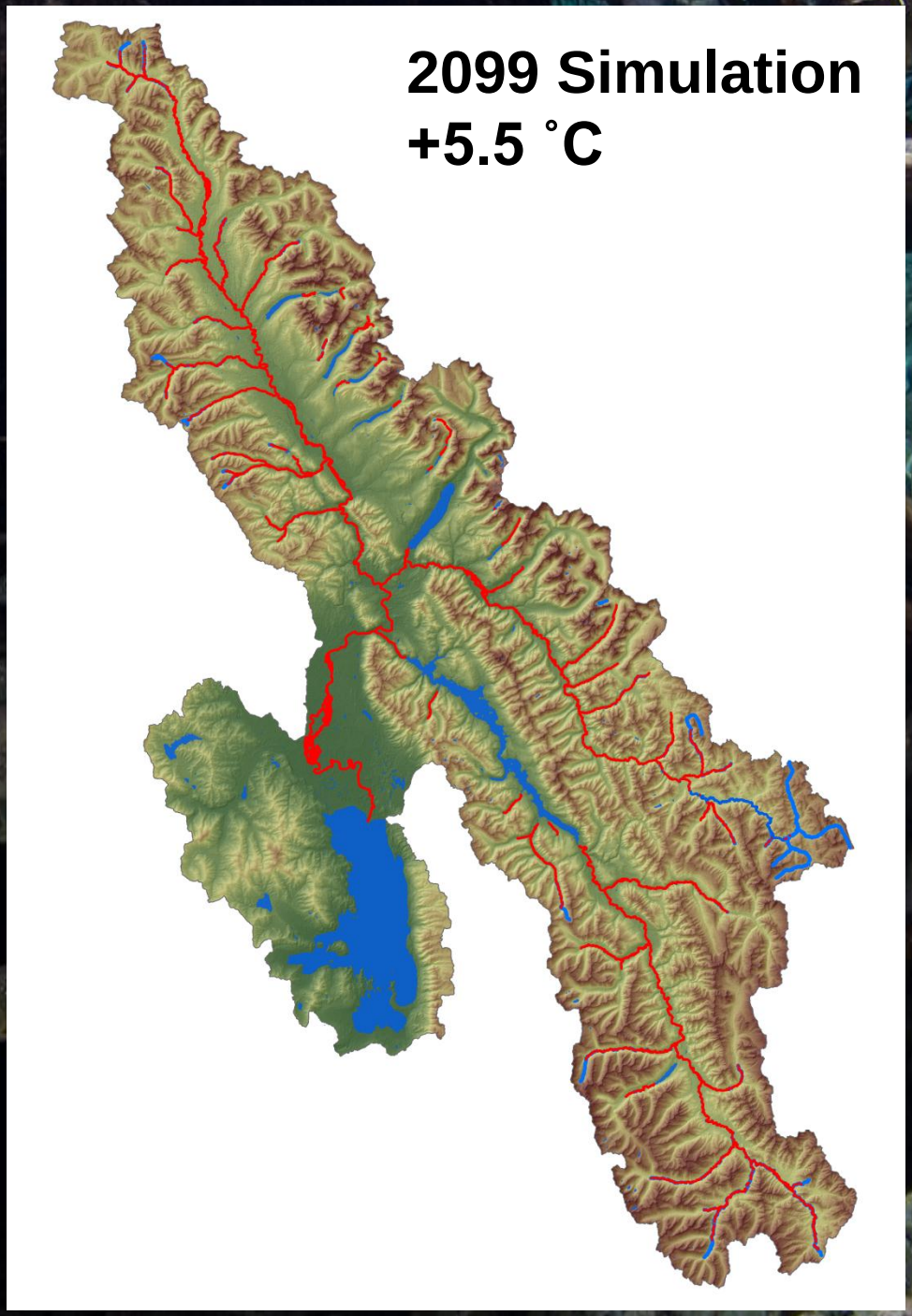


USGS
science for a changing world

J. Sartore

- **86% Loss of FMO**
- **76% Loss of SR**

Exceedence of Thermal Thresholds



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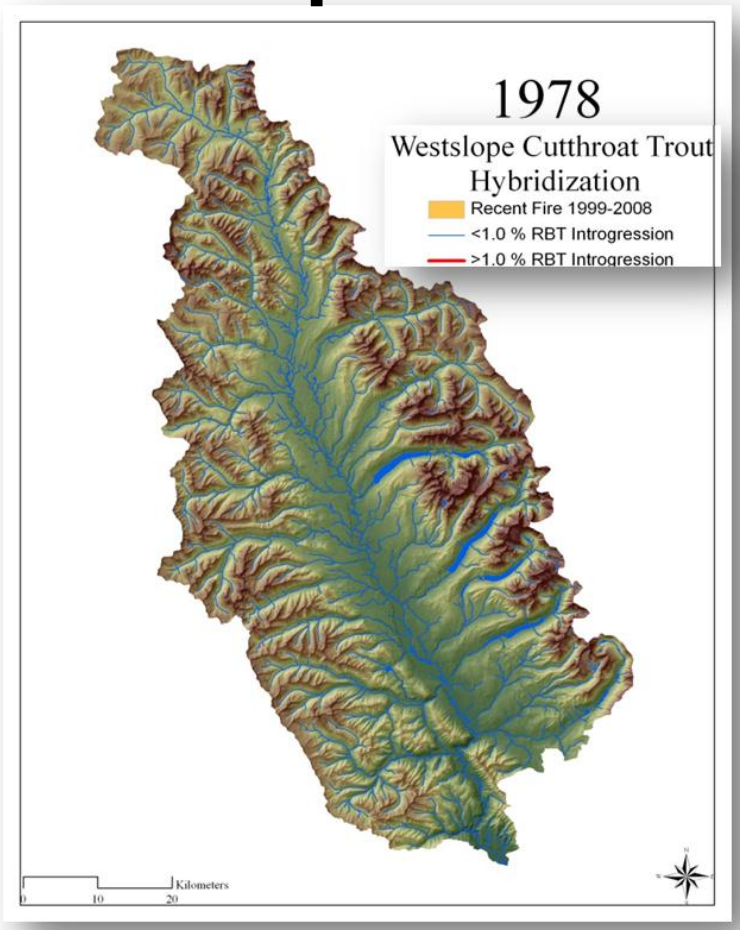
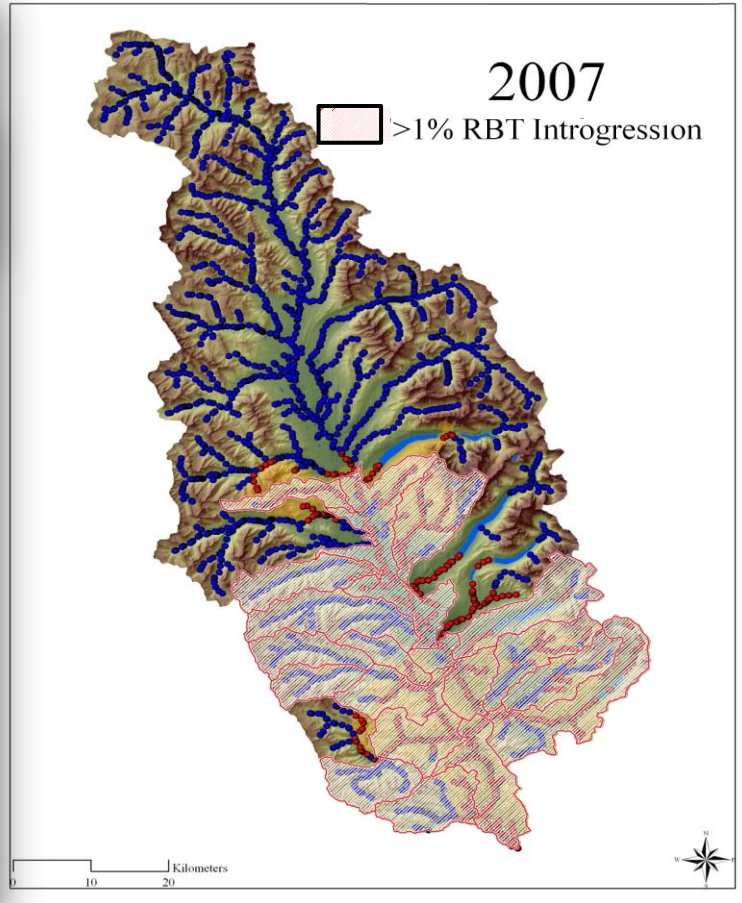
Jones et. al. (In press)

Retrospective analysis of hybridization





Stream Temperature

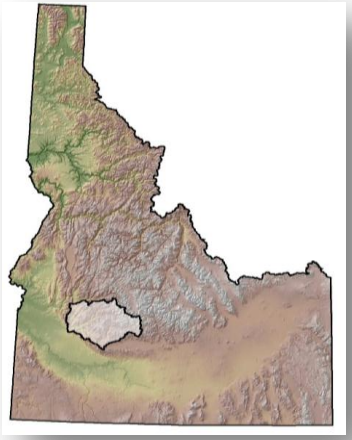
- **<9.0 Celsius**
- **>9.0 Celsius**

Hybrids have greater straying rates (Boyer et al. 2008)

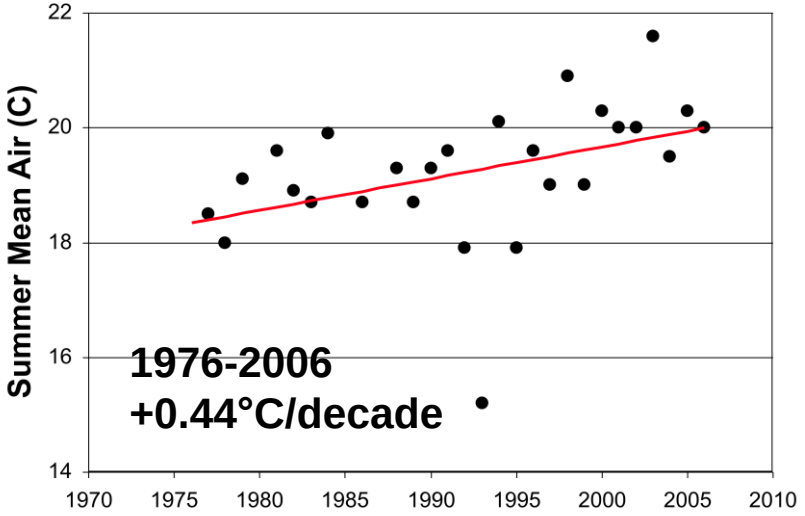
Spreading via continent island and stepping stone invasion (Muhlfeld et al. 2009)

Hybridization is greater in warm, degraded streams (Muhlfeld et al. 2009 TAFS)

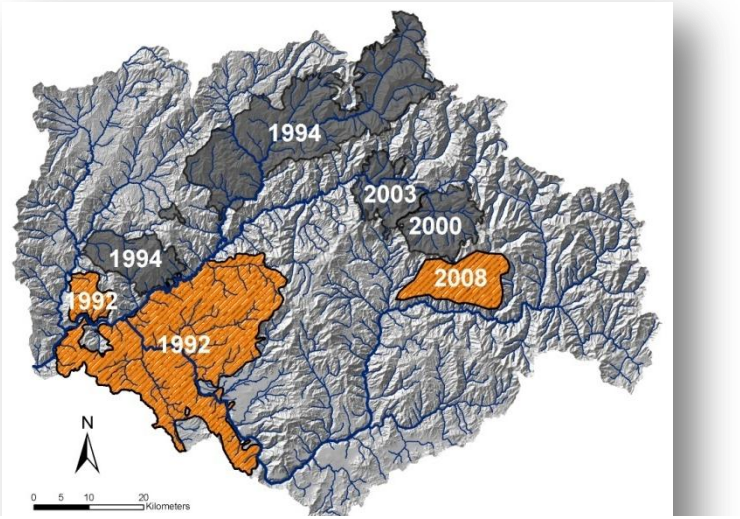
Boise River historical climate changes



August Air Temperature

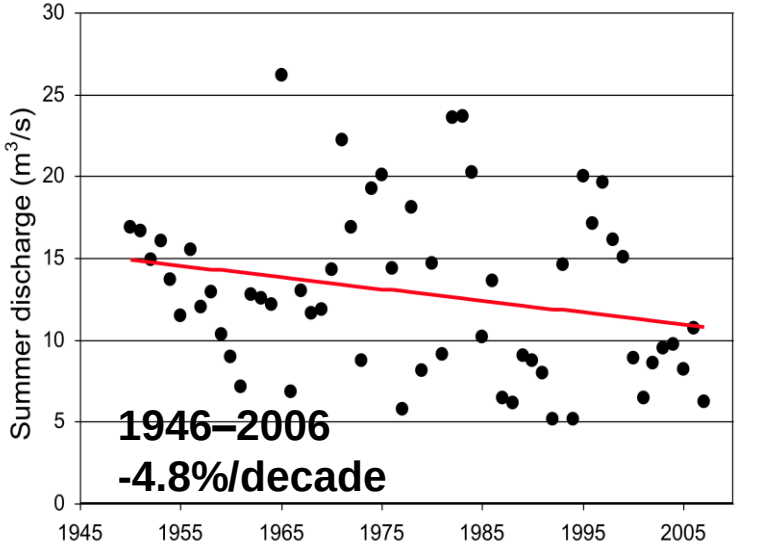


Recent Wildfires



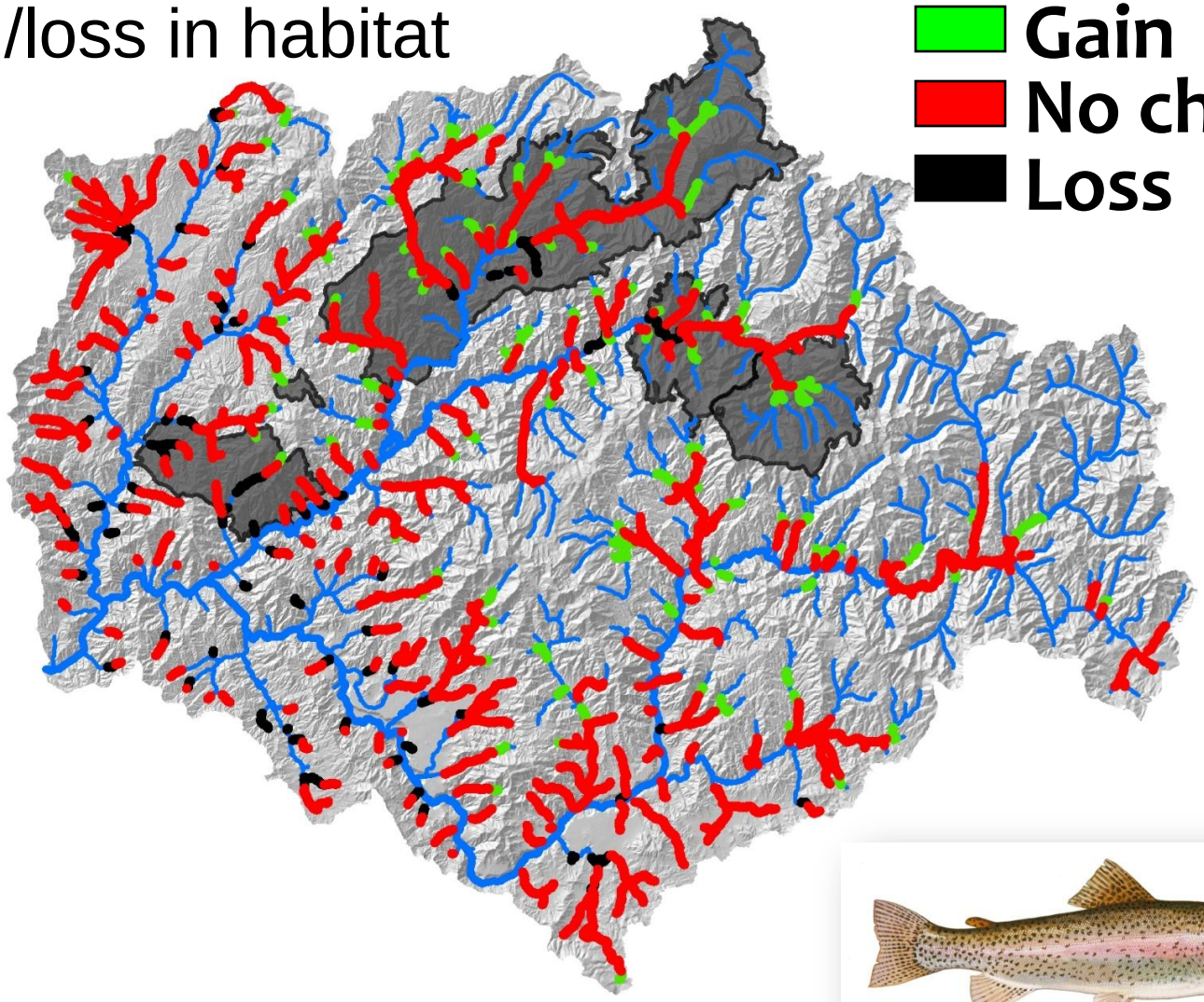
30% burned from 1992-2008

Summer discharge



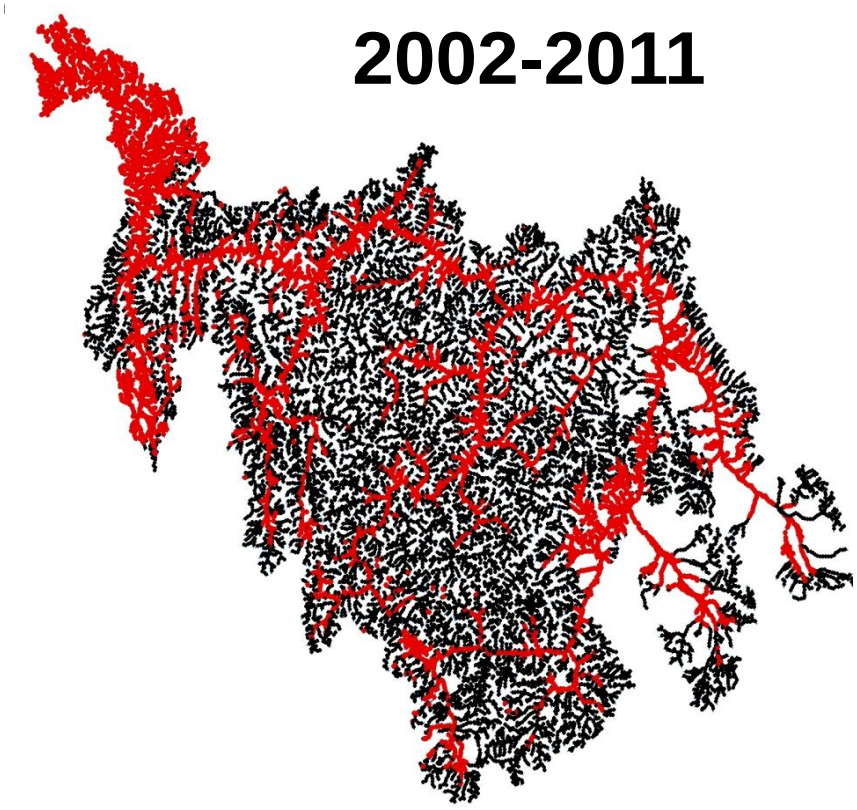
Changes in Rainbow Trout Habitat (1993-2006)

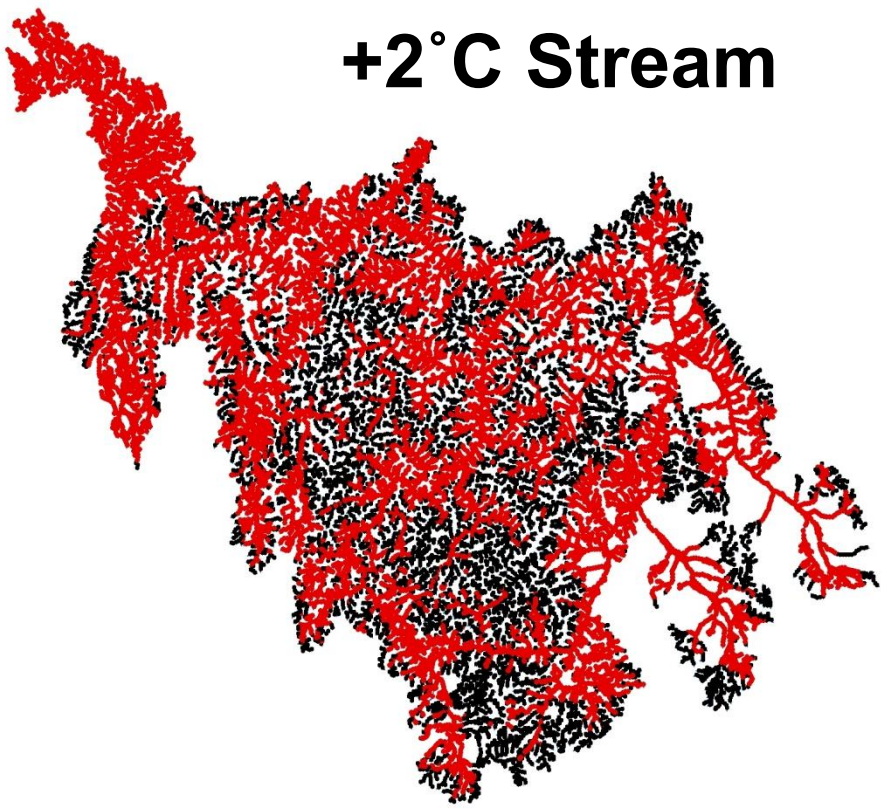
No net gain/loss in habitat



Isaak et al. 2010. *Ecol. Apps.* **20**:1350-1371

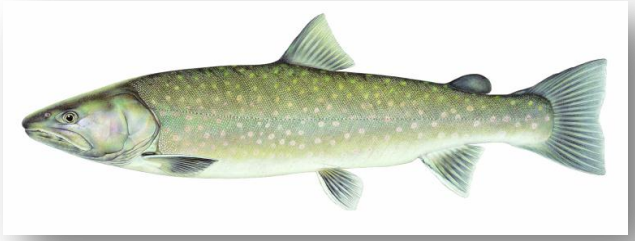
Potential habitat loss of up to 63% by 2056



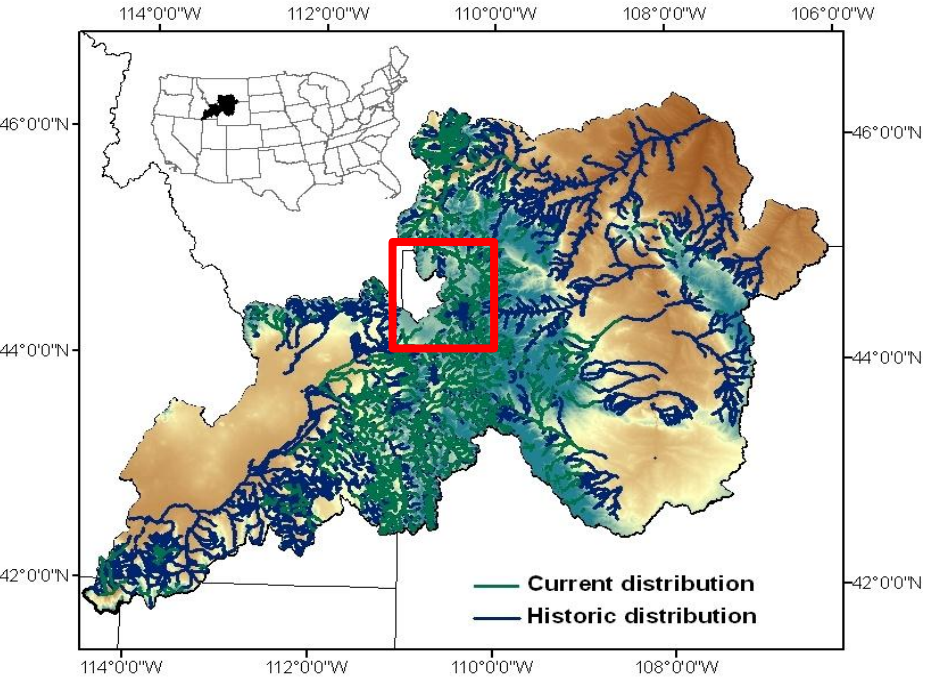


Suitable

Unsuitable



Yellowstone Cutthroat Trout



WILDLIFE CONSERVATION SOCIETY

USGS science for a changing world

Al-Chokhachy et al., submitted

Yellowstone cutthroat trout distribution

- Similar issues to WCT
- Somewhat different landscapes
- Similar stressors
- Add water withdrawal/irrigation
- Two major river systems
  - Snake and Yellowstone

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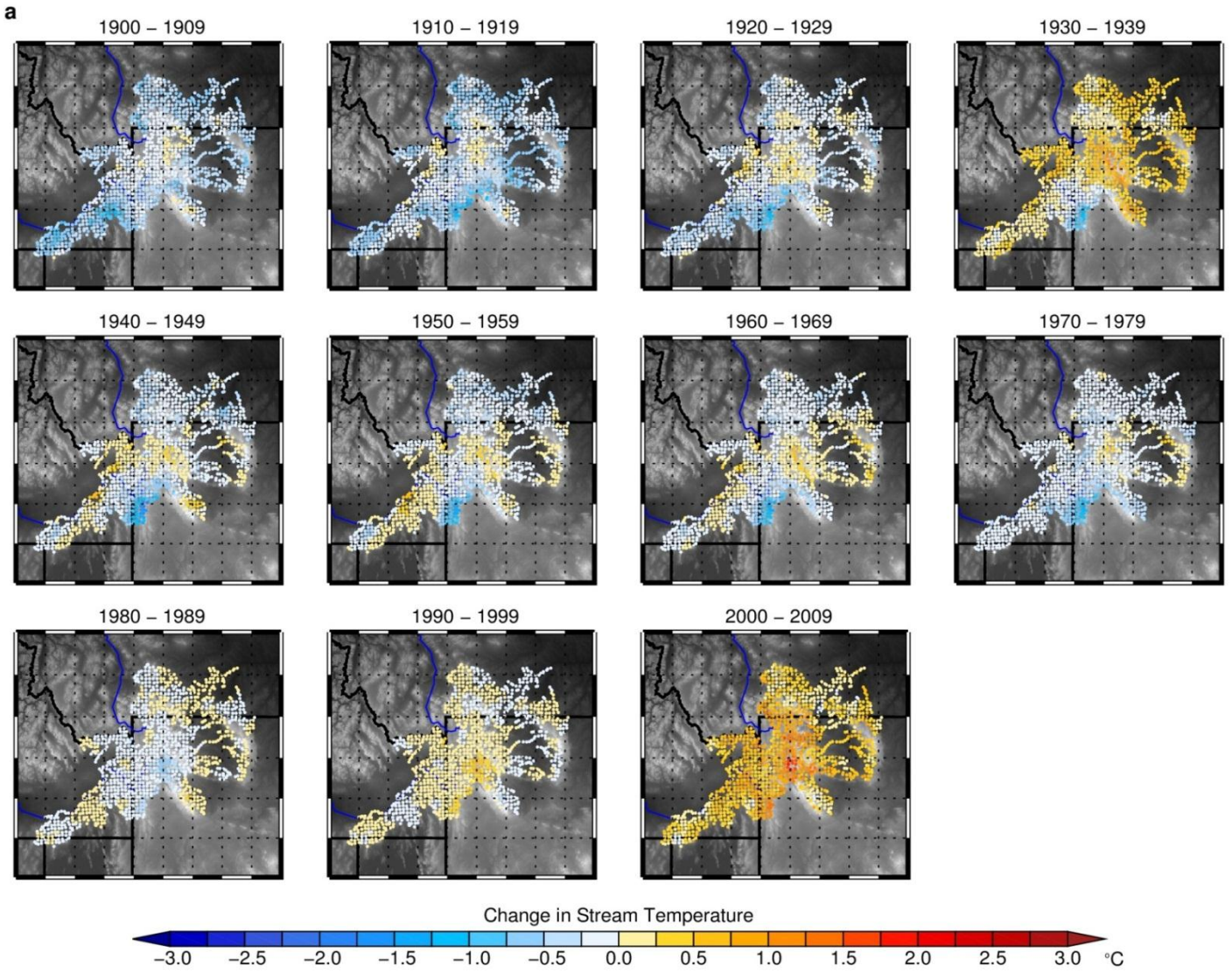
Stream temperature regression model

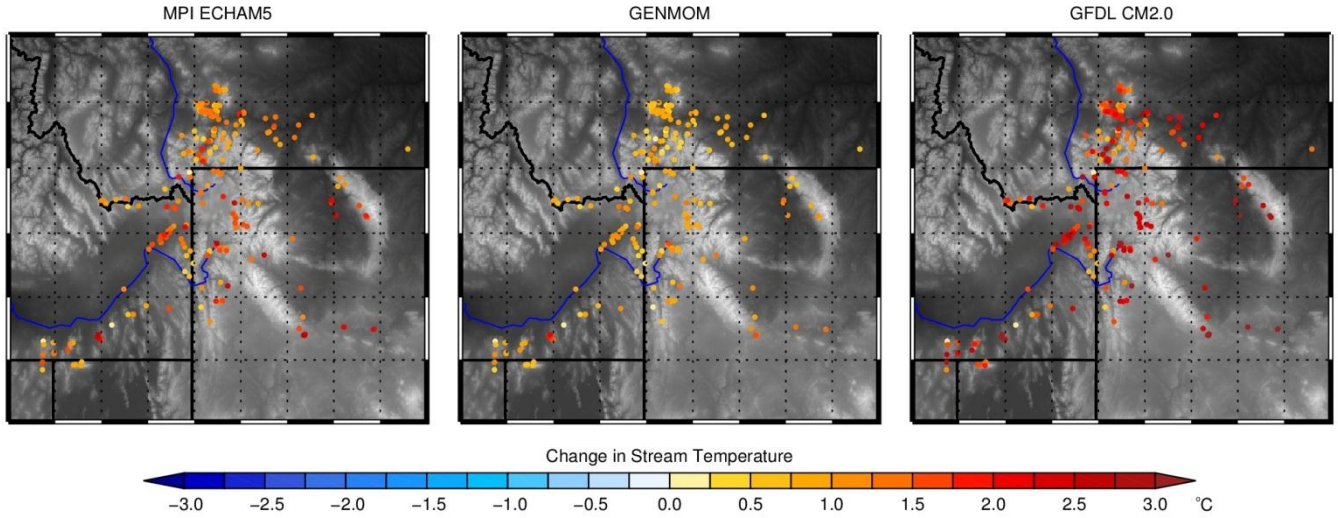
(May-Sep. daily 556,411 air and 152,539 stream temperatures)

Reconstructed 20th century May-Sep stream temperature

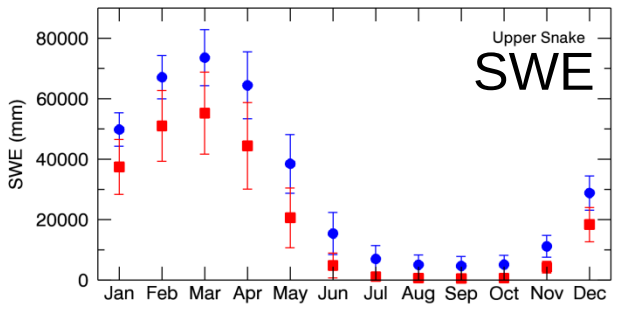


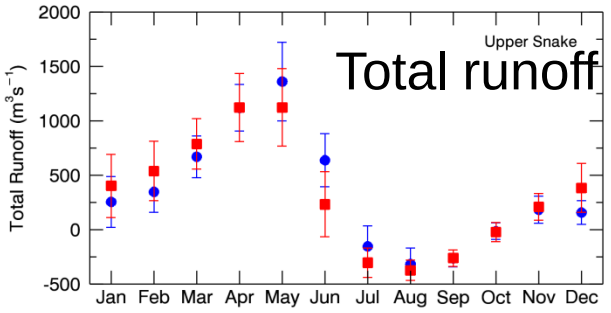
RegCM3 2050-2059 changes

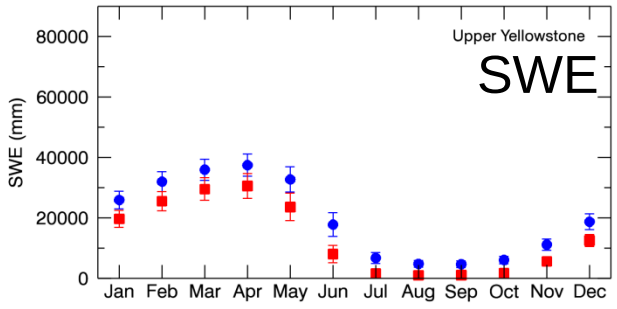
Stream temperature

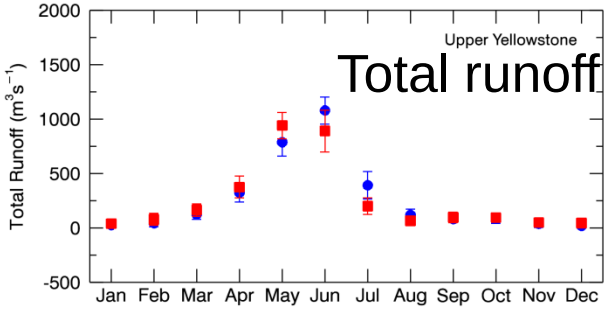


Hydrology

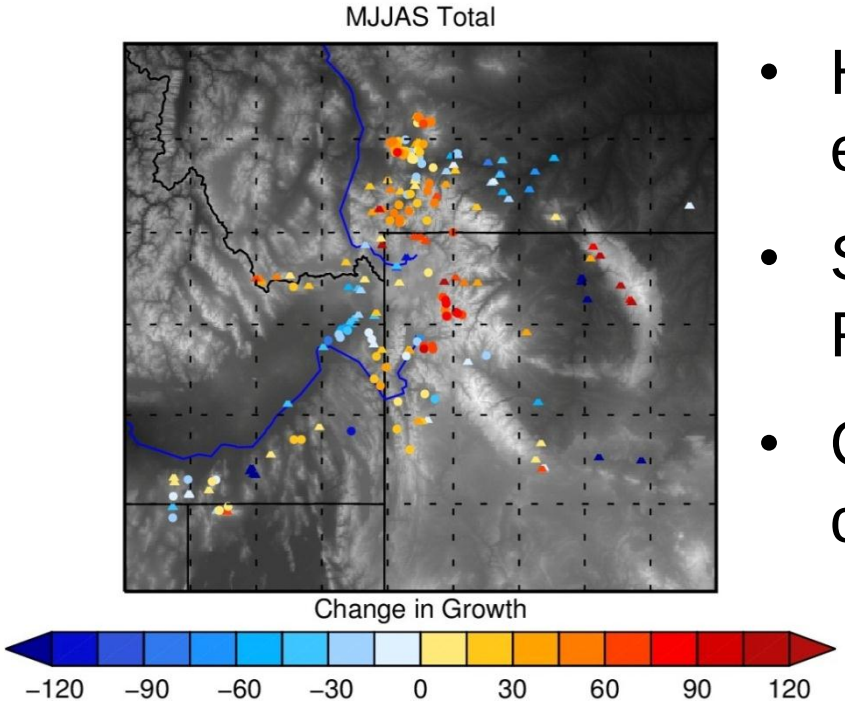




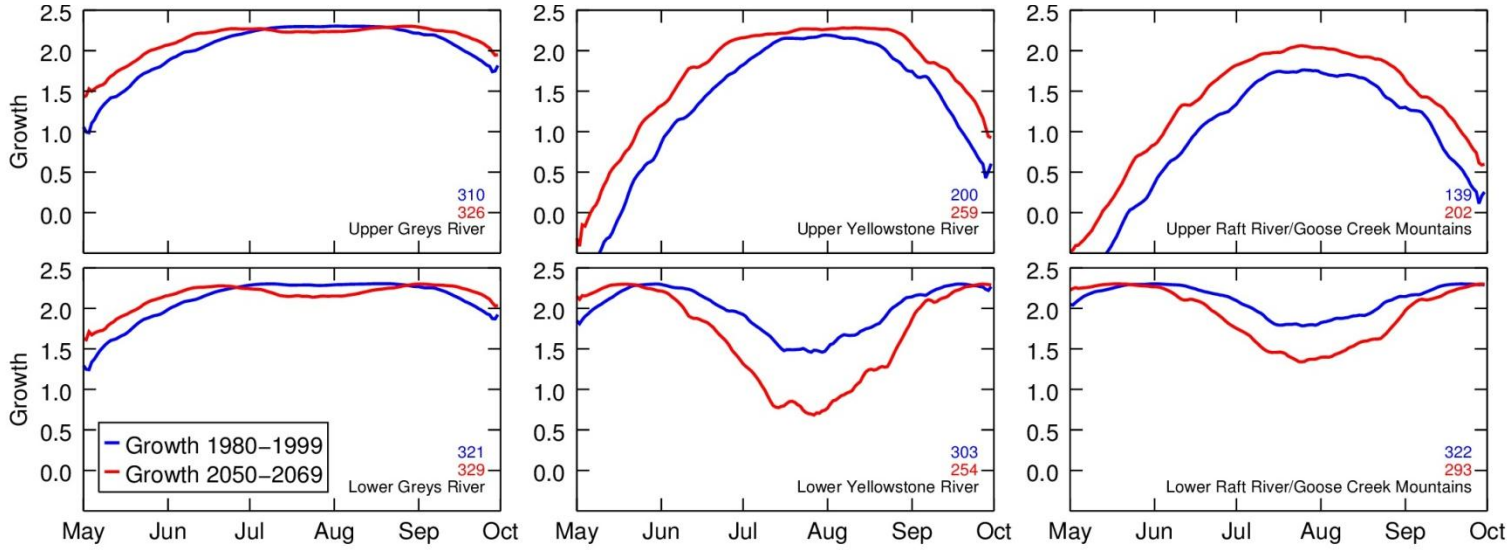




Change in YCT growth potential



- High elevation gains offset low elevation losses
- Sympatric populations YCT and RBT winners and losers
- Connectivity will be increasingly critical?



Colorado River Cutthroat Trout

Question

- What are the effects of climate change and fragmentation on persistence of populations?

Prediction

- Populations at lower latitudes and elevations, and those in shorter fragments, will be less likely to persist

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Roberts et al, in revision

Bayesian Network: Predicting CRCT persistence

Maximum Stream Temperature-MWMT

Warmest 30-day Temperature-M30AT

Stream fragment length

Population Size (genetic risks)

Stochastic effects

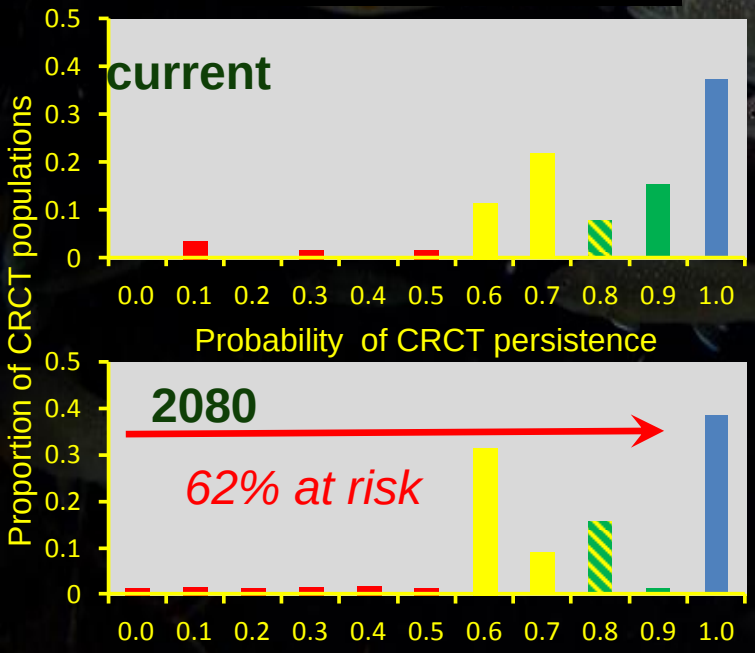
Habitat potential

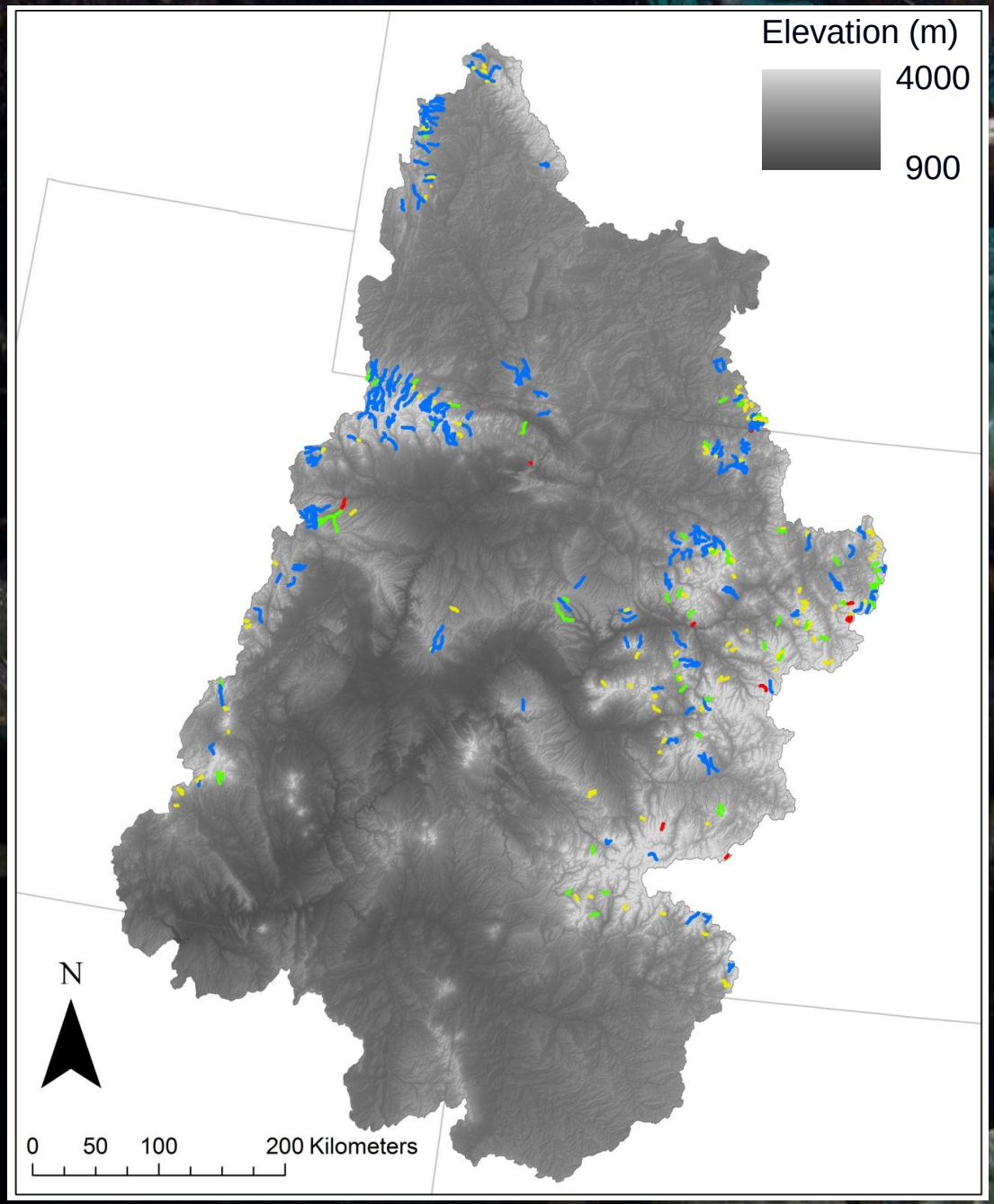
Probability of CRCT Population Persistence

- Time horizon
  - 2040 and 2080

Population persistence

Probability of persistence





Bottom Line…..CRCT

- Risk from warming is low: Already restricted to high, cold streams by invasions
- 62% of CRCT populations at risk: Due to small fragment size
- Opportunities for conservation: Increase fragment length
- Future work
  - modeling change in fragment length versus risks
  - climate change, mountain lakes

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Vulnerability of the Rio Grande Cutthroat Trout to Climate Change

- Small populations
- Warming streams
- Disturbance
- Declining flows
- Fragment size

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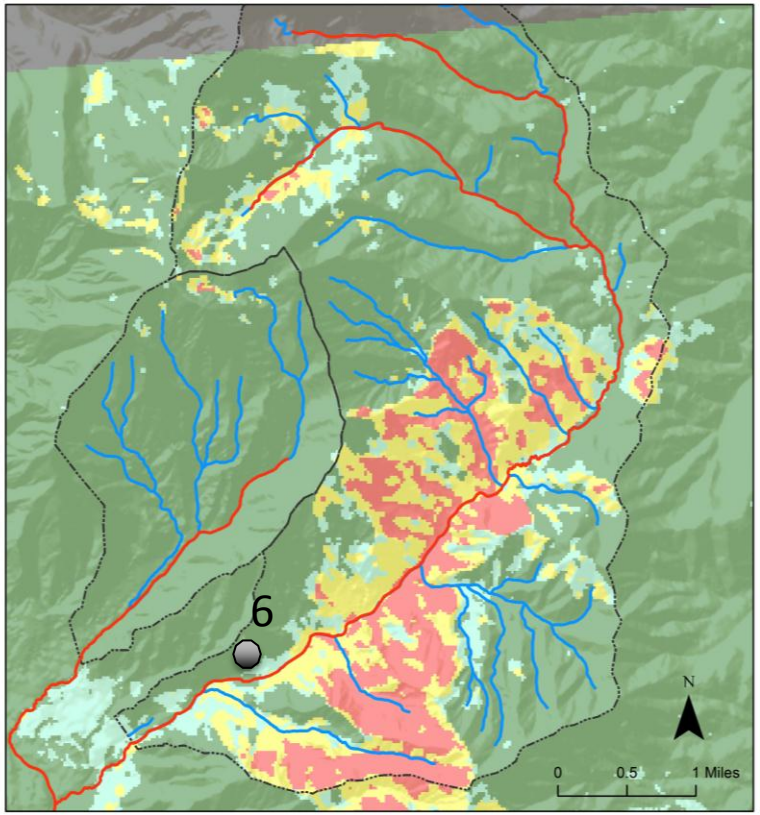
Rio Grande cutthroat trout from Prong Creek, Saguache County, CO

Climate-influenced stochastic variables
Medano Creek, CO fire (2010)

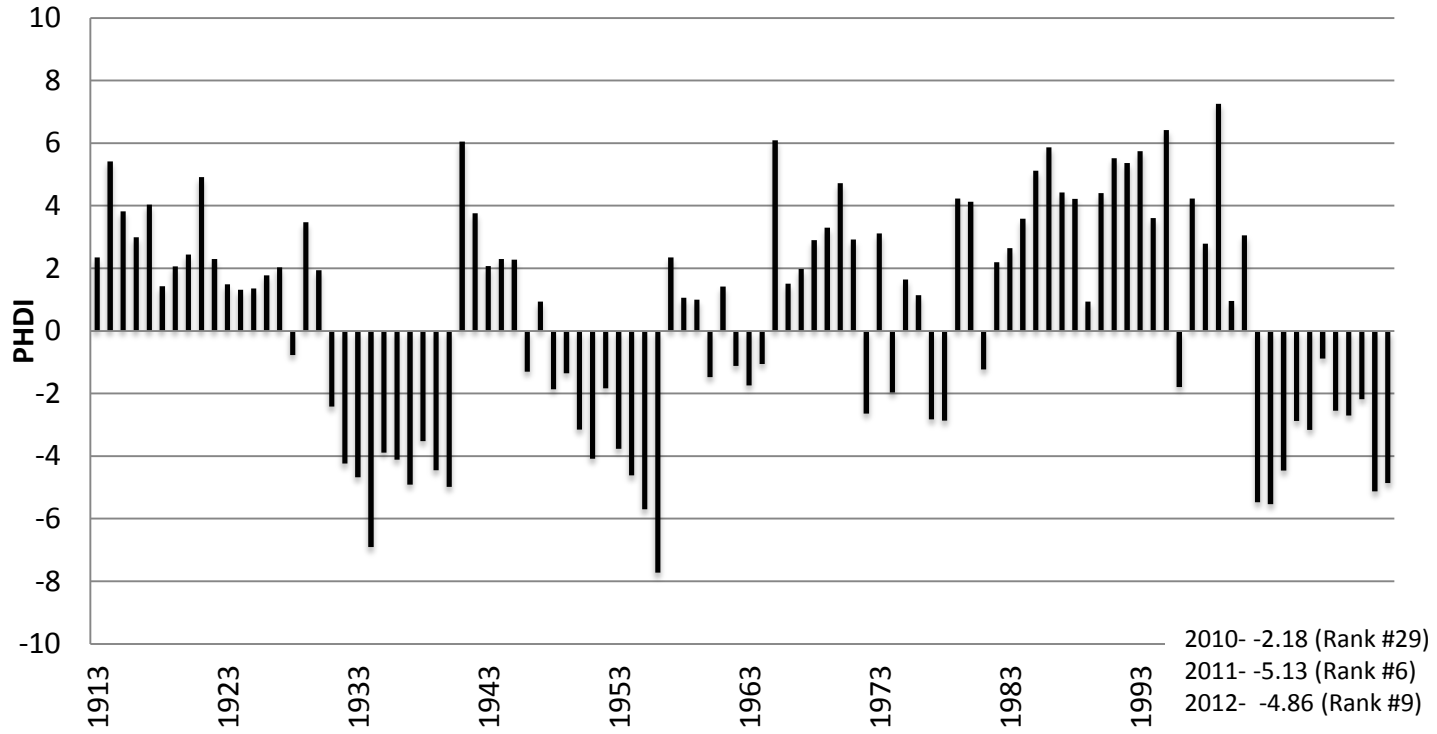


RGCT Density at Station #6

- 2004: 460 fish / mile
- 2005: 481 fish / mile
- 2008: 457 fish / mile
- 2011: 191 fish / mile

Electrofishing data courtesy of Colorado Division of Parks and Wildlife

Drought Index for the Rio Grande Headwaters (September)



Data obtained from NOAA Website

Take home messages

- Climate change will further compound existing stressors
- Perhaps the greatest risk is to small, isolated and peripheral populations
- Restoration action should be considered in high risk/high value habitats to increase resistance and resilience to climate change
- Managers need easily understandable methods to evaluate management actions in the face of climate uncertainty

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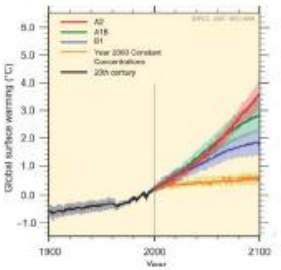
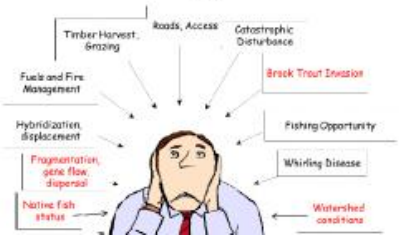
How do we use all this stuff?

Bringing it all together…



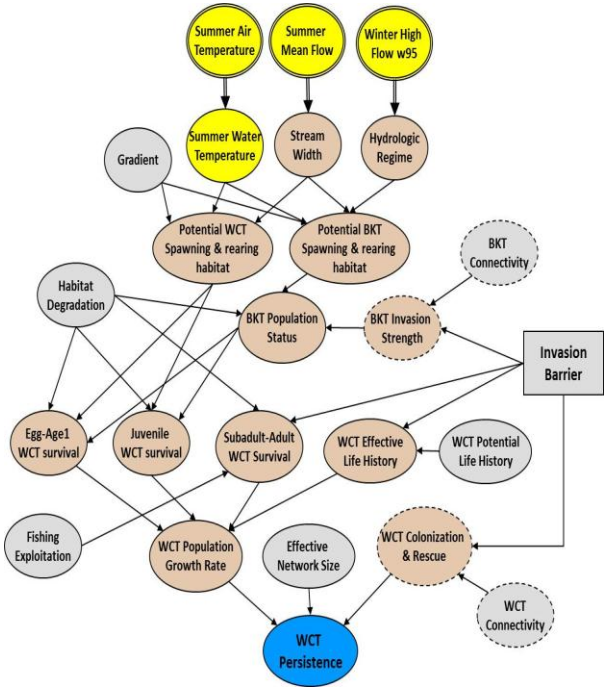
Decision space and uncertainty

- *Prediction error, complexity, non-stationarity*



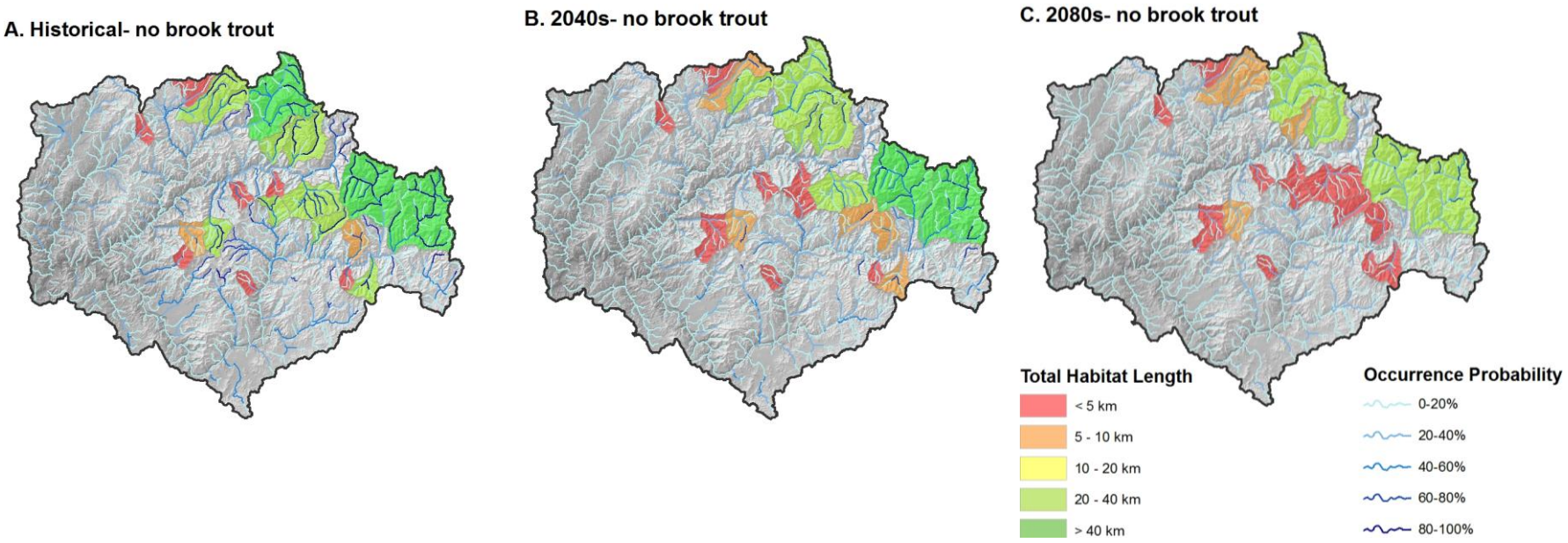
Linking data to a decision framework

- *Bayesian network (BN) approach*



Peterson et al., in press, *Fisheries*

West slope cutthroat persistence probability



Peterson et al., in press, *Fisheries*

Information Products

- 9 Journal articles (Accepted, In Press, Published)
- Multiple journal articles (in preparation or submitted)
- 3 Open File reports
- 4 symposia held in conjunction with professional society meetings
- 5 workshops with species technical committees (Example)

Project websites

Climate modeling and climate data usage:
http://regclim.coas.oregonstate.edu

Information on climate and effects on native trout project:
http://nrmsc.usgs.gov/research/climate_trout

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Workshops

Understanding and Adapting To Climate Change in Aquatic Ecosystems at Landscape and River Basin Scales: A decision support workshop for integrating research and management

Workshop hosted by the U.S. Forest Service-Rocky Mountain Research Station, with co-sponsorship from the U.S. Geological Survey, Trout Unlimited, and the Great Northern Landscape Conservation Cooperative.

Workshop goals were to gather a diverse group of researchers and management professionals to focus on three objectives:

1) sharing current information regarding the effects of climate change on aquatic ecosystems,

2) presenting analysis tools that could assist managers in addressing climate change, and

3) discussing management implications of climate change, the utility of existing tools, and future information & analysis needs.

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What's Next?

- NorWest – A collaborative project with GNLCC
- Longer term research questions
- Continued/expanded monitoring
- Forecasting for the near future – helping managers with today's issues

NorWeST: A Regional Stream Temperature Database & Model for High-Resolution Climate Vulnerability Assessments

Dan Isaak, Seth Wenger[1], Erin Peterson[2], Jay Ver Hoef[3] Charlie Luce, Steve Hostetler[4], Jason Dunham[4], Jeff Kershner[4], Brett Roper, Dave Nagel, Dona Horan, Gwynne Chandler, Sharon Parkes, Sherry Wollrab

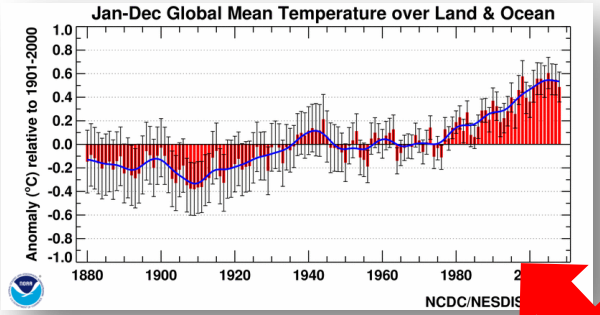
U.S. Forest Service

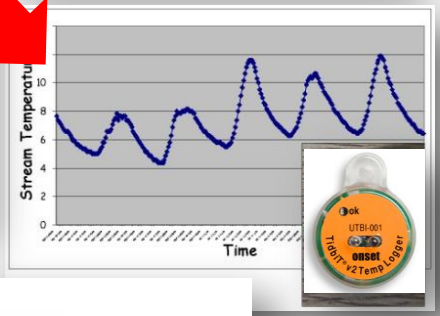
[1]Trout Unlimited

[2]CSIRO

[3]NOAA

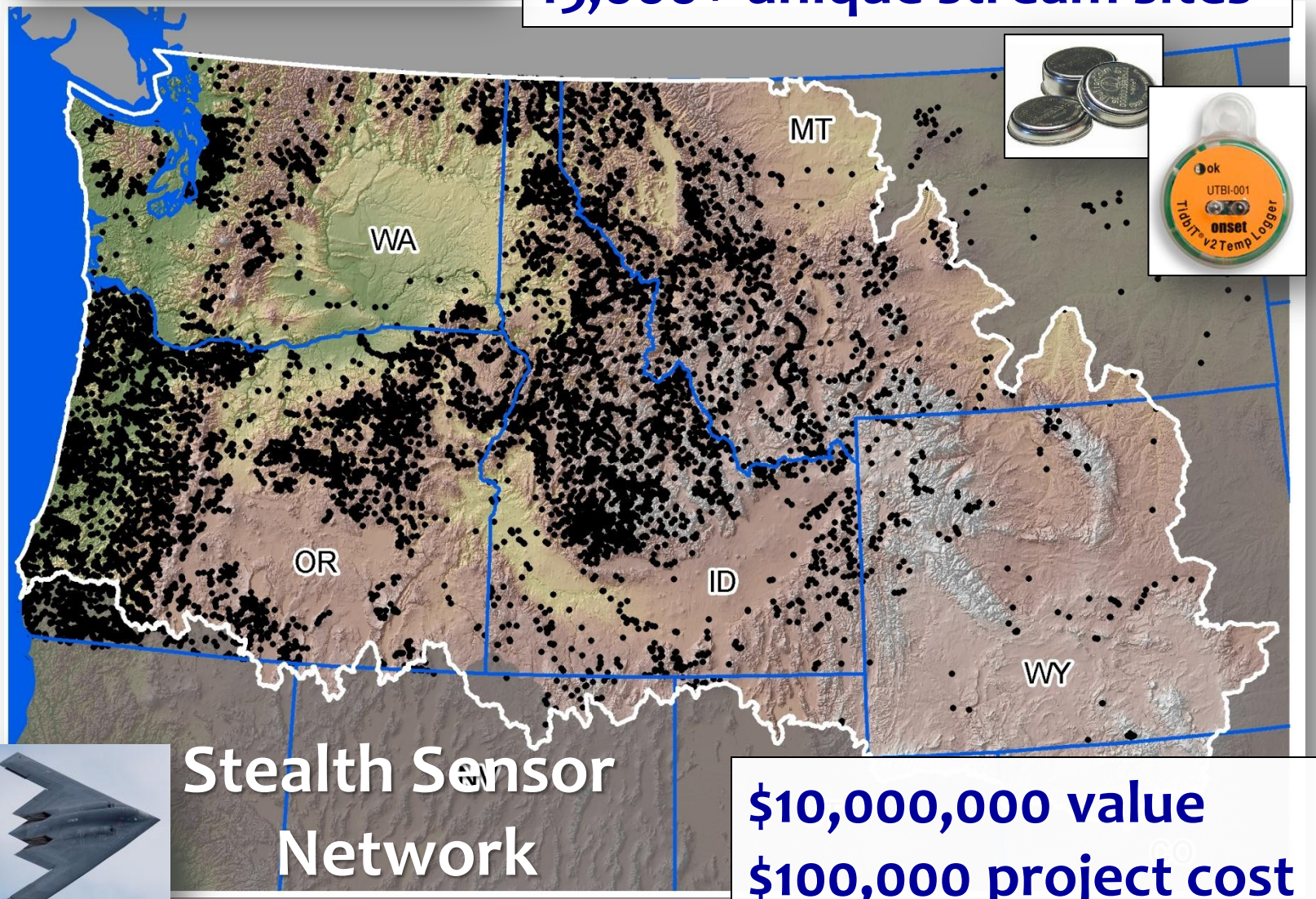
[4]USGS





NorWeST Stream Temp

45,000,000+ hourly records
45,000+ summers measured
15,000+ unique stream sites



Stealth Sensor Network

$10,000,000 value
$100,000 project cost

More Precise Bioclimatic Assessments

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Forest and Rangeland Ecosystem Science Center

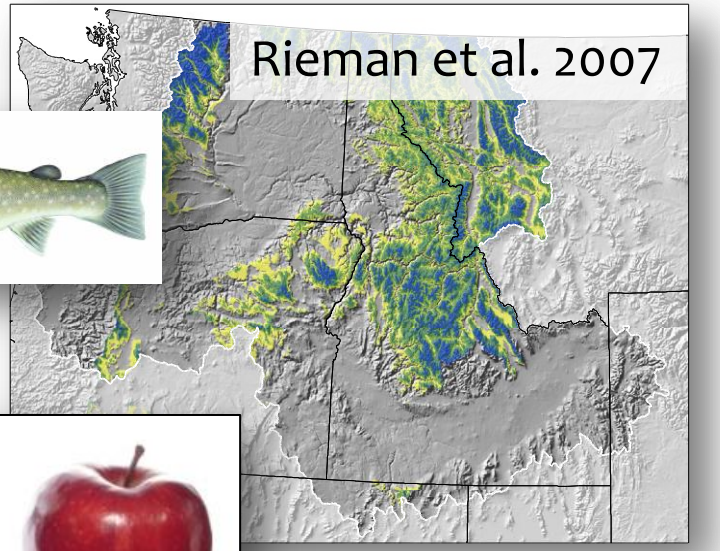
Range-wide climate vulnerability assessment for bull trou... conterminous United S...

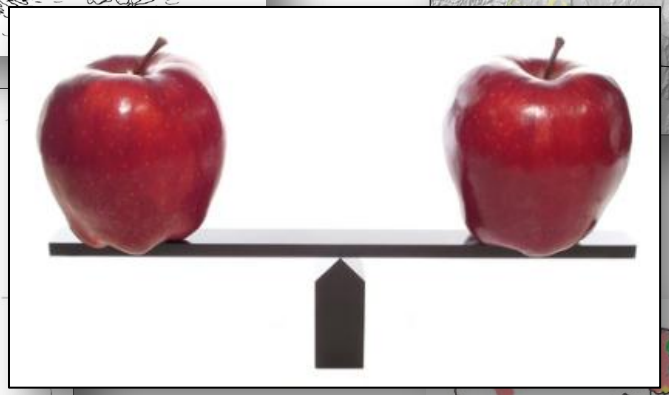
"Judging by one criterion, it is Extinct!"

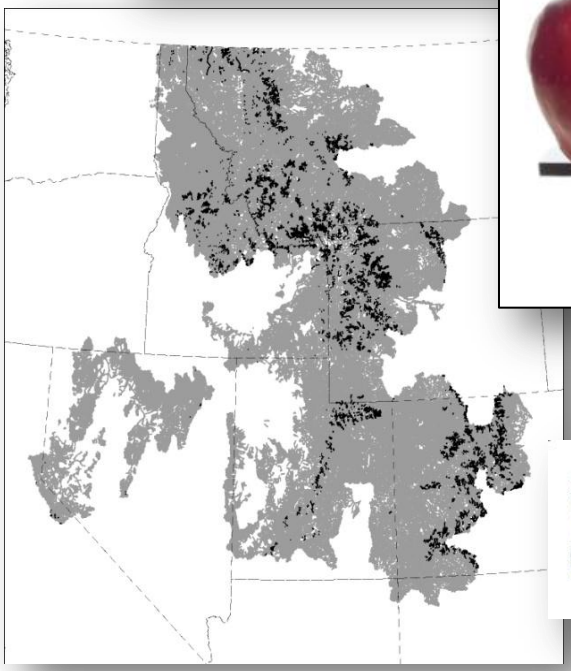
"But judging by ar... alive and healthy ..."

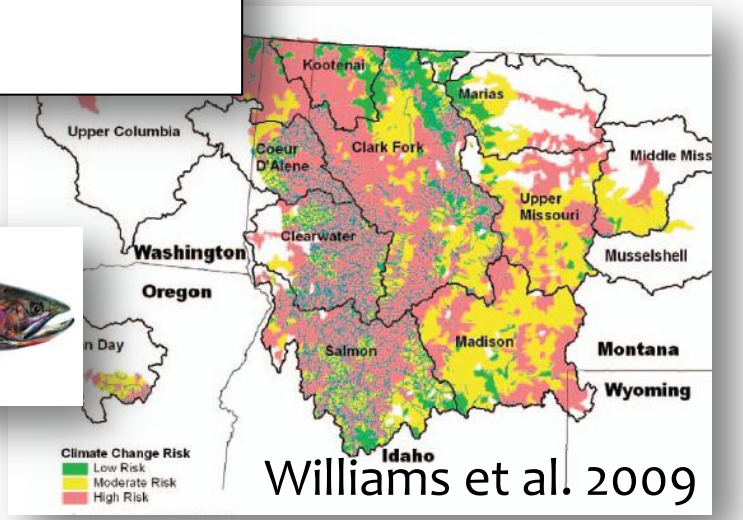
Dunham et al., In prep.

Rieman et al. 2007





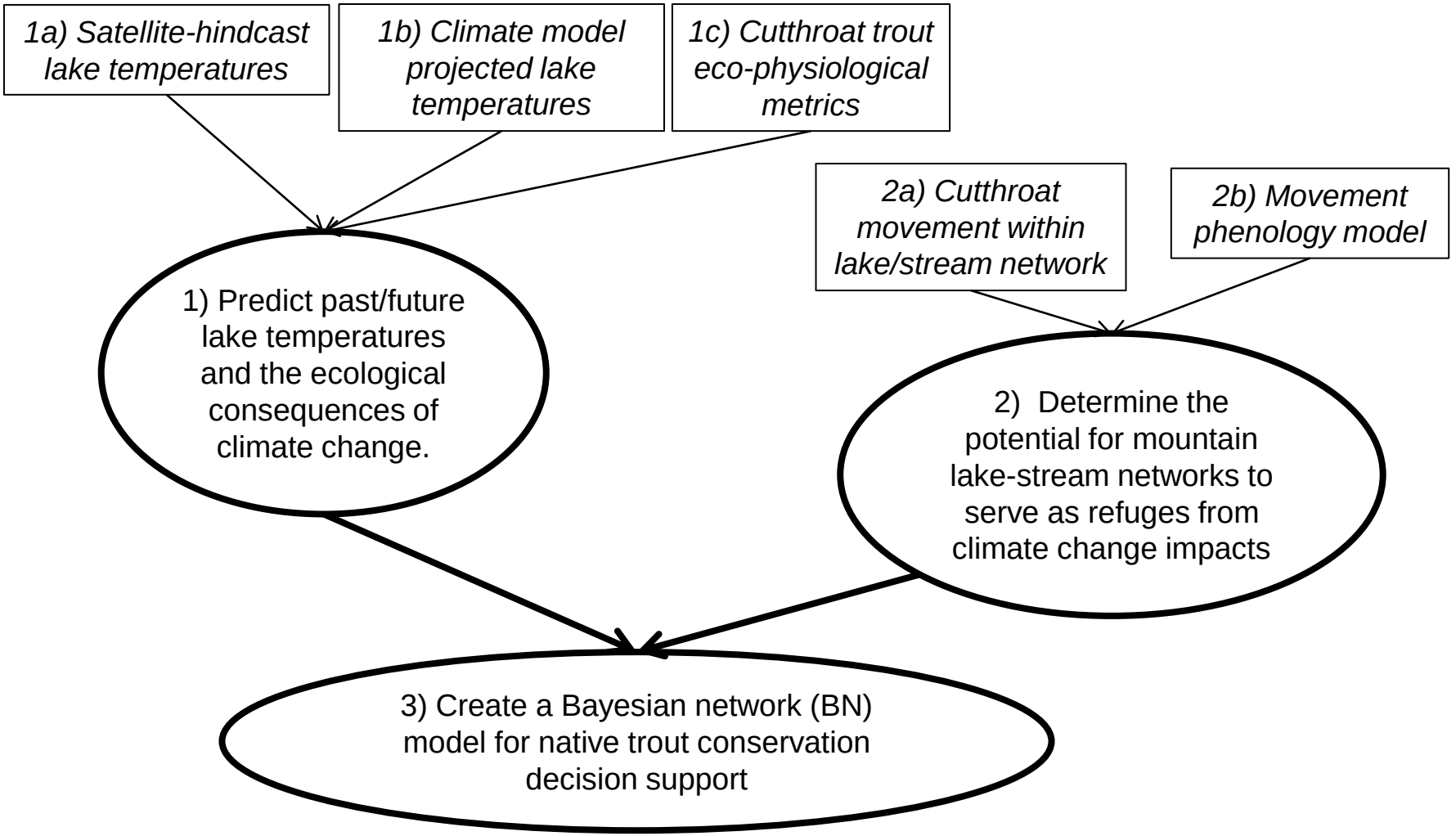




Wenger et al. 2011. *PNAS*.

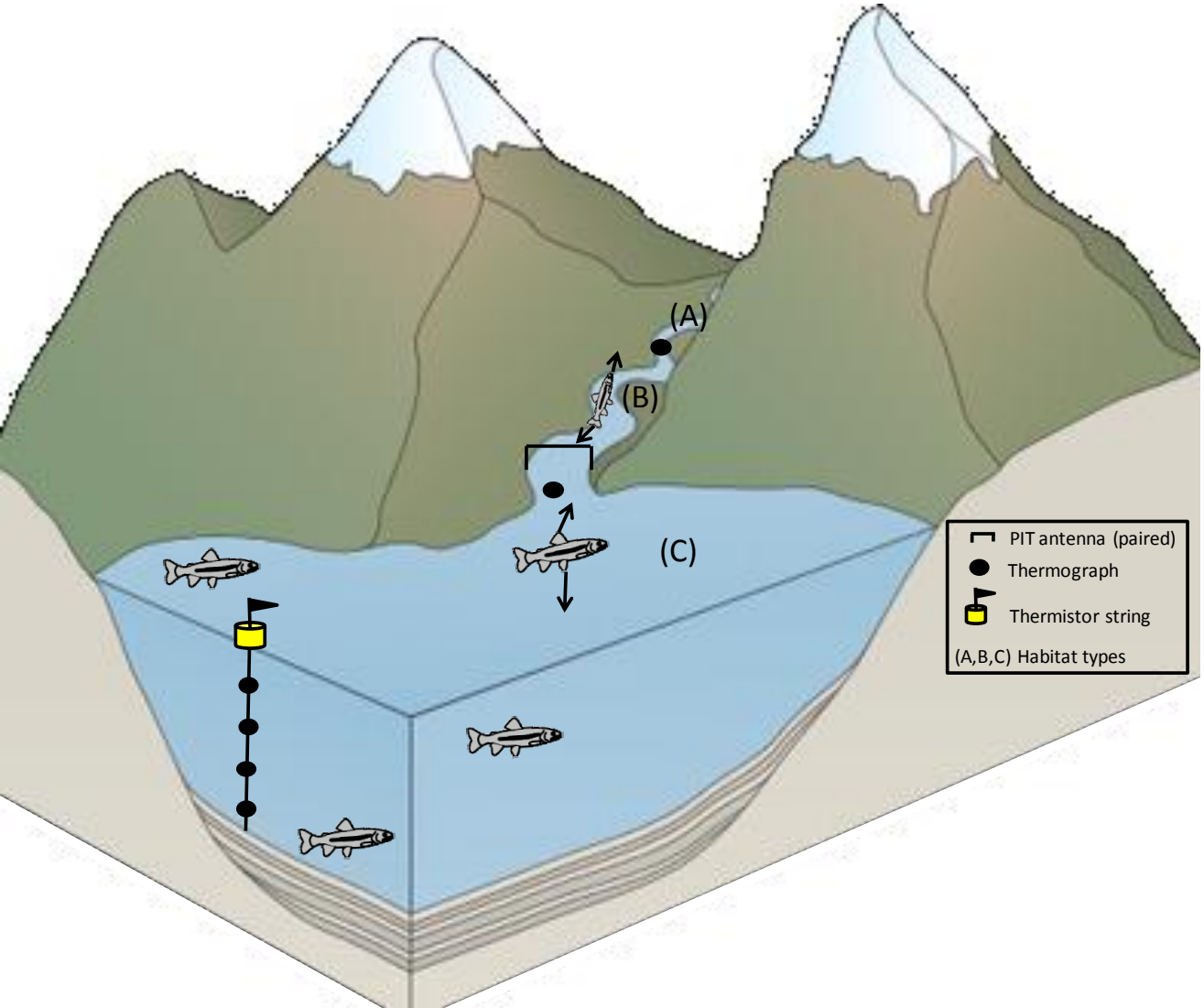
Williams et al. 2009

Future research: climate change, mountain lakes, and cutthroat trout



Roberts et al., 2012

Climate change, mountain lakes, & cutthroat



- Thermal changes
- Fish movement
- Perform modeling and field research
- 2 lake-stream networks
  - Thermographs
  - PIT tag antennas

Long-term monitoring

- Are our predictions right?
  - invasive species, population response
- Integrated watershed responses to climate change and disturbance
- Improve models
- Better informed management decisions

Moving our long-term climate science to the present

- What do managers need now?
  - Big Hole, MT
- Summer stream closures
- Rates of change: invasive species, population persistence (Rio Grande)

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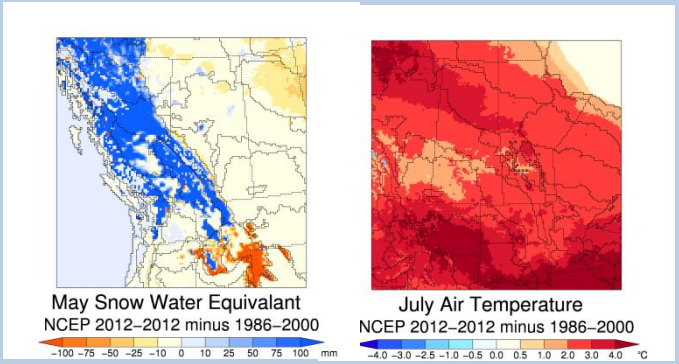
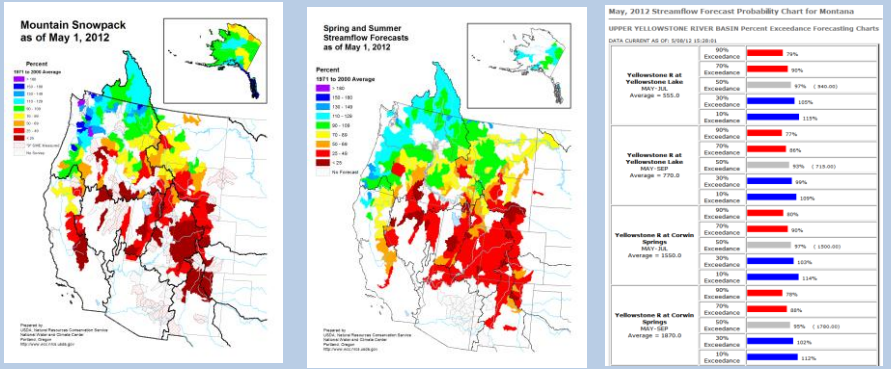
Near-term stream temperature guidance

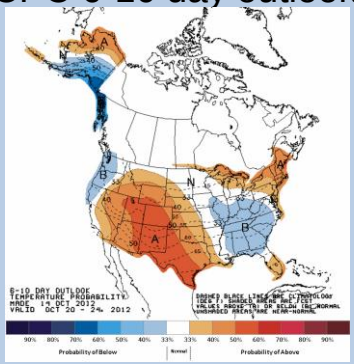
RegCM3 simulations



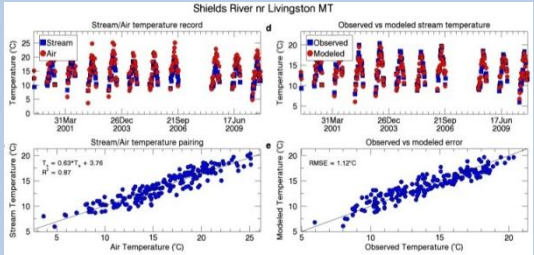
SNOTEL, flow forecasts + observations



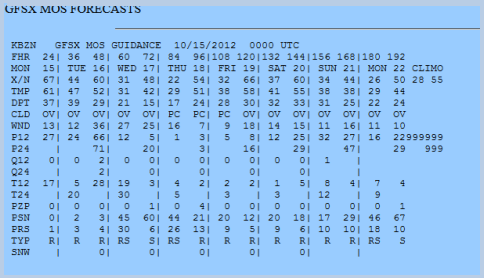
CPC 6-10 day outlook



$T_{water} \sim f(T_{air}, Q)$

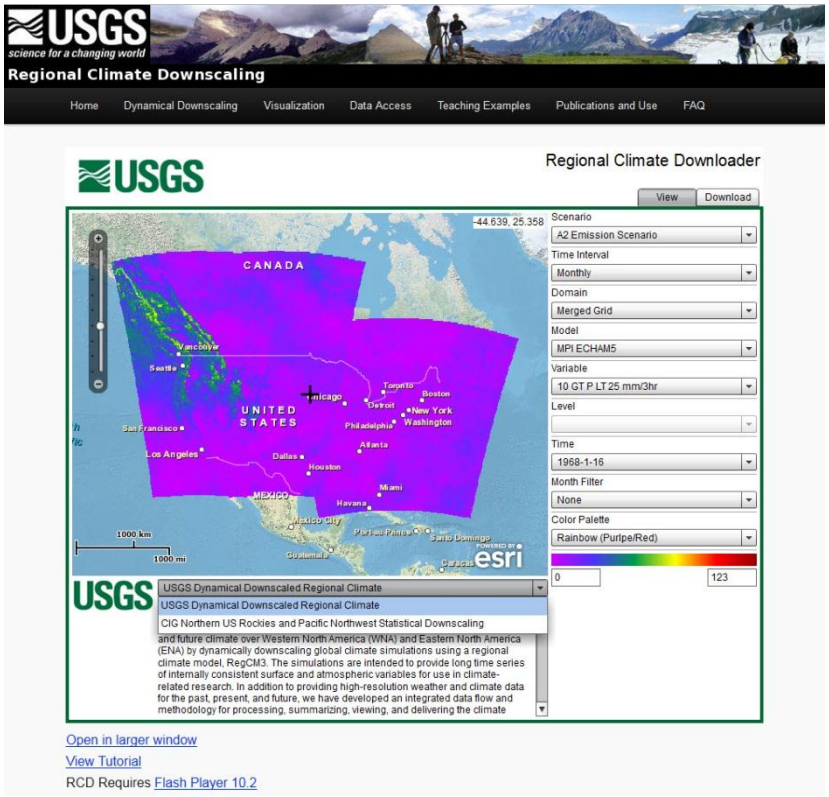


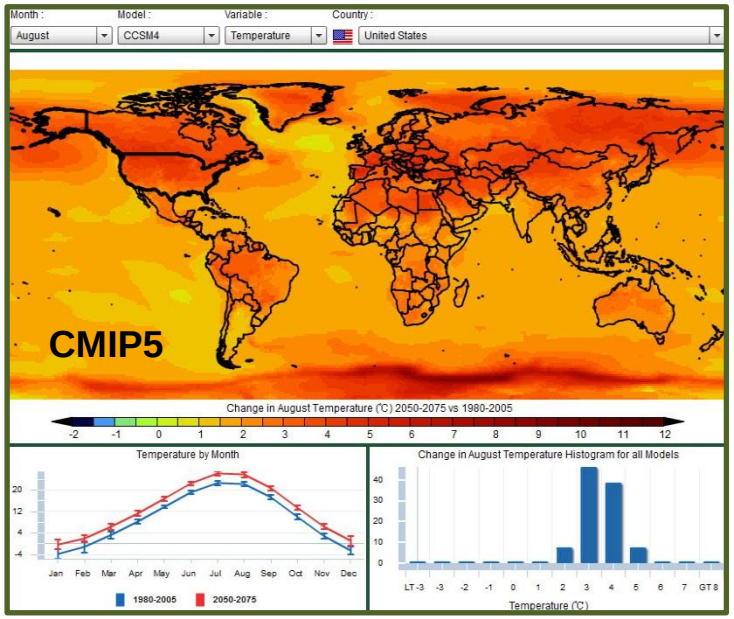
NWS 7-day forecast

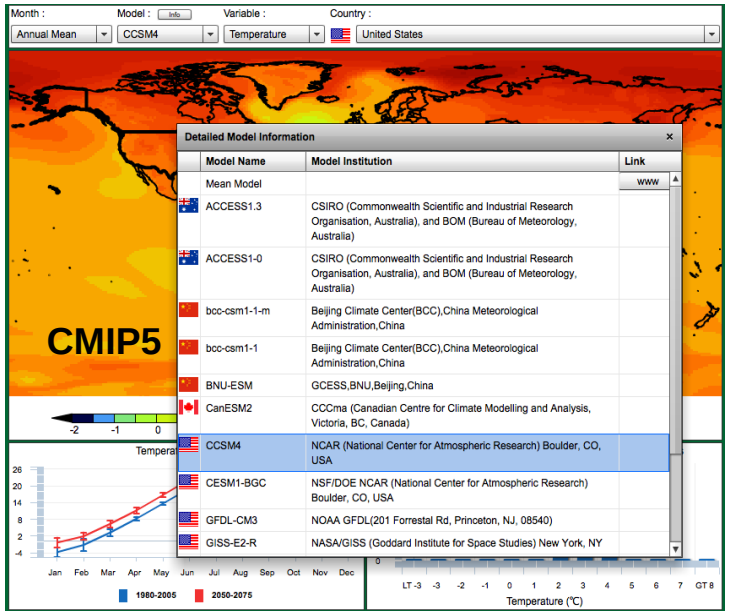


$$P[flow \cap temp] = P[flow]P[temp]$$

New data sets







- WNA 30-arcsec bioclimatic
- Climate analogues
- Global paleoclimate
- Regional paleoclimate


Questions?
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